

75p.

MSFC

MTP-P&VE-M-62-6

March 5, 1962

g e-1



N64-17607

CODE-1

TPX-54517

**GEORGE C. MARSHALL**

**SPACE  
FLIGHT  
CENTER**

**HUNTSVILLE, ALABAMA**

AGING OF INSTALLED RUBBER AND PLASTIC  
GASKETS IN SIMULATED FLIGHT HARDWARE

By

S. L. Burt  
J. M. Stuckey  
L. M. Thompson

NASA. TPX 54517

PROPERTY OF  
TECHNICAL LIBRARY  
MS-IPL

OTS PRICE

XEROX

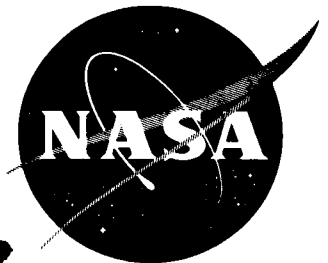
\$

2.60 *ref.*

MICROFILM

\$

2.45 *ref.*



**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

GEORGE C. MARSHALL SPACE FLIGHT CENTER

---

MTP-P&VE-M-62-6

---

AGING OF INSTALLED RUBBER AND PLASTIC  
GASKETS IN SIMULATED FLIGHT HARDWARE

By

S. L. Burt  
J. M. Stuckey  
L. M. Thompson

ABSTRACT

17607 *ner* *A*  
A study of the combined effect of time and atmospheric conditions (ambient temperature, humidity, and oxidation) on the functional reliability of selected gasket materials was begun in April, 1959.

Initially, eight types of rubber, three plastics, and four commercial gaskets (metal and rubber o-rings, Flexitallic, and Allpax) were installed as static seals in conventional flange connectors (bolted and Marman types). Dynamic sealing in three types of solenoid operated valves equipped with rubber o-ring seals was included in the study. Each type of rubber is being tested in two shapes, namely, o-rings and flat gaskets.

Pressurization testing of installed gaskets for leakage rate measurements was run semi-annually.

Accelerated ozone aging, air bomb aging, and compression set tests were carried out in the laboratory for determining the relative age resistance of several types of rubber, and these tests provided a means of measuring the progress made in the development of improved age resistant stocks. Outdoor weathering tests were run parallel with accelerated laboratory testing to further advance the meager understanding of correlating the results of these two methods of testing.

Currently, thirteen types of rubber are being tested. The installed gasket program, in progress at the Marshall Space Flight Center, is duplicated exactly at Gainesville, Florida under contract with the University of Florida (NAS8-1523). ~~XXXXXXXXXX~~

17607

This report covers the activities during the first two and one-half years of the aging program. Flexitallic gaskets in aluminum flanges failed the 750 psi pressure test after six months at MSFC (one year at Gainesville, Florida) of installed life. Flexitallic gaskets in stainless steel flanges failed after one and one-half years of installed life at both locations. Allpax gaskets, tested at 500 psi pressure, failed the initial test at MSFC and after two years at Gainesville. None of the rubber (commercial or domestic) or plastic gaskets have failed the pressure test due to aging during the time interval covered by this report.

*Author*

GEORGE C. MARSHALL SPACE FLIGHT CENTER

---

MTP-P&VE-M-62-6

---

AGING OF INSTALLED RUBBER AND PLASTIC  
GASKETS IN SIMULATED FLIGHT HARDWARE

By

S. L. Burt  
J. M. Stuckey  
L. M. Thompson

ENGINEERING MATERIALS BRANCH  
PROPULSION AND VEHICLE ENGINEERING DIVISION  
GEORGE C. MARSHALL SPACE FLIGHT CENTER  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
HUNTSVILLE, ALABAMA



## TABLE OF CONTENTS

	Page
INTRODUCTION.....	2
MATERIALS.....	3
A. RUBBER GASKETS.....	3
B. PLASTIC GASKETS.....	4
C. COMMERCIAL GASKETS.....	4
TEST FIXTURES.....	4
A. TEST LOCATION.....	5
B. INSTALLATION OF GASKETS IN TEST FIXTURES.....	5
C. PANEL DESCRIPTION.....	5
TEST PROCEDURES AND RESULTS.....	6
A. ACCELERATED OZONE TEST.....	6
B. AIR BOMB ACCELERATED TEST.....	7
C. COMPRESSION SET OF VULCANIZED RUBBERS - METHOD B .....	7
D. OUTDOOR WEATHERING.....	7
E. INSTALLED GASKET TESTING.....	8
F. INSTALLED GASKET AGING TEST RESULTS.....	9
DISCUSSION OF RESULTS.....	10
A. THEORY OF AGING IN ELASTOMERS .....	10
B. ACCELERATED AGING TEST RESULTS .....	13
CONCLUSIONS.....	14
REFERENCES .....	67

## LIST OF ILLUSTRATIONS

### Appendix A

Table	Title	Page
1	Rubber and Plastic Gasket Materials.....	16
2	Typical Physical Properties of Different Rubbers.....	17
3	Test Assembly Torque Pressures and Lubricants Employed on Gaskets.....	18
4	Effect of 25 PPHM Ozone on Rubber Samples Test Conditions: Temperature-Ambient Time -48 Hours.....	19
5	Effect of 100 PPHM Ozone on Rubber Samples Test Conditions: Temperature-Ambient Time -1000 Hours.....	20
6	Effect of 500 PPHM Ozone on Rubber Samples Test Conditions: Temperature-Ambient Time -1000 Hours.....	21
7	Air Bomb Test of Several Types of Rubber Test Conditions: Temperature - 127°C Time - 48 Hrs. Air Pressure- 80 psi.....	22
8	Compression Set of Elastomers.....	23
9	Resistance of Rubber Sample to Surface Cracking in Outdoor Weathering at MSFC.....	24
10	Aging of Rubber Gaskets at MSFC.....	25
11	Aging of Plastic Gaskets at MSFC.....	28
12	Aging of Commercial Gaskets at MSFC.....	29
13	Aging of Rubber Gaskets at Gainesville, Florida.....	30
14	Aging of Plastic Gaskets at Gainesville, Florida.....	33
15	Aging of Commercial Gaskets at Gainesville, Florida...	34
16	Effect of Pressure on Aging Characteristics of Rubber Gaskets at MSFC.....	35

## LIST OF ILLUSTRATIONS (CONT'D)

### Appendix A (Cont'd)

Table	Title	Page
17	Effect of Pressure on Aging Characteristics of Rubber Gaskets at Gainesville, Florida.....	38

### Appendix B

#### Drawing

MR-73-1	Flange Assembly Thrust Chamber.....	41
MR-73-2	Gasket Test Assembly.....	42
MR-73-3	Gasket Test Assembly.....	43
MR-73-4	Gasket Test Assembly.....	44
MR-73-5	Gasket Test Assembly.....	45
MR-73-6	Gasket Test Assembly.....	46
MR-73-7	Gasket Test Assembly.....	47
MR-73-8	Gasket Test Assembly.....	48
MR-73-9	Valve Assembly Solenoid MV-76.....	49
MR-73-10	Control Valve MV-74.....	50
MR-73-11	LOX Replenishing Valve.....	51

### Appendix C

Test Procedure No. 1.....	52
Test Procedure No. 2.....	53
Test Procedure No. 3.....	54
Test Procedure No. 4.....	55

## LIST OF ILLUSTRATIONS (CONT'D)

### Appendix D

Figure	Title	Page
1	Test Facilities at Gainesville, Florida.....	57
2	Test Fixture Assembly.....	58
3	Installed Test Fixtures.....	59
4	Installed Test Fixtures at MSFC.....	60
5	Mast Ozone Test Chamber.....	61
6	Accelerated Ozone Aging of Natural Rubber (25 PPHM Ozone at Ambient Temperature).....	62
7	(a) Air Bomb Apparatus.....	63
	(b) Test Specimens.....	63
8	(a) Outdoor Aging Rack.....	64
	(b) Outdoor Aging Specimens.....	64
9	Outdoor Aging of Natural Rubber Showing the Development of Ozone Crack in Bent Loop Specimens.....	65
10	(a) Leak Rate Measurement.....	66
	(b) Leak Measurement Control Panel.....	66

GEORGE C. MARSHALL SPACE FLIGHT CENTER

---

MTP-P&VE-M-62- 6

---

AGING OF INSTALLED RUBBER AND PLASTIC  
GASKETS IN SIMULATED FLIGHT HARDWARE

By

S. L. Burt  
J. M. Stuckey  
L. M. Thompson

SUMMARY

A program was initiated in April, 1959, to determine the aging characteristics of various gasketing materials as affected by time, pressure, and atmospheric conditions (oxidation, humidity, and ambient temperature).

The installed gasket aging study is duplicated at the Marshall Space Flight Center and at Gainesville, Florida by contract with the University of Florida. Each type of material and shape of gasket is triplicated (excepting valves) at MSFC and Gainesville in order that a high level of confidence may be maintained in the results reported. Pressurization tests of the installed gaskets are run semi-annually. Failure is indicated when two out of three gaskets leak in excess of established tolerance rates (see page 8).

Accelerated laboratory tests (ozone, air bomb, and compression set) were used to determine the relative age resistance of the various types of rubber and to evaluate the progress made in the development of improved age-resistant stocks. Outdoor weathering tests were run parallel with the laboratory tests for additional information in correlating the results of these two methods of testing.

Initially (1959), eight domestically processed elastomers (natural, nitrile, butyl, styrene-butadiene, Neoprene, fluorosilicone, silicone, and Viton-A) in the forms of o-rings and flat gaskets; three plastics (Teflon, nylon, plasticized and unplasticized Kel-F) in the shape of flat gaskets only; and four commercial gaskets (Flexitallic, Allpax, metal and rubber o-rings) were installed as static seals in conventional flange connectors (bolted and Marman types). In September, 1960, three new elastomers (acrylic, Hypalon, and Kel-F) were added to the program. In April, 1961, two new elastomers (Thiokol and urethane) were added. Currently, thirteen types of elastomers and five improved formulations (nitrile, Hypalon, acrylic, silicone and fluorosilicone) are under study.

In October, 1961, the program was expanded to include the study of the effects of aging at three test pressures (up to 1000 psi) on the sealing characteristics of o-rings and flat gaskets for thirteen types of elastomers. Three types of solenoid operated valves equipped with rubber and/or plastic seals were included to determine the effect of aging on dynamic seals.

This report covers the results of the first two and one-half years of the aging program. Flexitallic gaskets, tested at 75 and 200 psi pressure, were sealing adequately after two years. All the Flexitallic gaskets tested at 750 psi pressure in aluminum fixtures leaked excessively after one-half year of installed life at MSFC and one year at Gainesville; in stainless steel fixtures, two-thirds failed after one and one-half years. Allpax gaskets, tested at 500 psi pressure, failed the initial test at MSFC. Similar gaskets at Gainesville failed after two years of aging. None of the rubber or plastic gaskets installed at the beginning of this program have failed due to aging.

## INTRODUCTION

Prior to 1940, only natural rubber was commercially available. By 1950, at least six synthetic rubbers had appeared, some of which have particular properties superior to those of natural rubber. Today, over fifteen types of synthetic rubber (including synthetic "natural" rubber) are marketed in commercial quantities, and many others are under development by various institutions across the nation. Individually, these elastomers differ in physical, mechanical, thermal, and chemical properties. A comprehensive knowledge of these properties is essential today in order to design and produce reliable rocket systems.

Aging in high polymers may be defined as the process of chemical reversion, or degradation in the physical properties, due to the influence of humidity, heat, cold, radiation, ultraviolet light, and time, or other specific environment such as prolonged stressing by compression or extension.

This program was initiated due to the lack of available information on the aging characteristics of various rubber and plastic materials, particularly as applied to gaskets under compression which are required to operate at fairly high pressures. Initially, the chief concern was the length of time that a ballistic missile containing rubber and/or plastic gaskets could be stored and remain operationally reliable. The reliability of gasket materials has become much more critical with the advent of manned space craft. The long-range scope of the program was intended to determine the effect of time, atmospheric conditions, and physical deformation on the service life of different types of gasket materials installed in typical flight component hardware.

Eight rubbers, three plastics, and four commercial gaskets were initially installed in conventional vehicle hardware. The program was

expanded and presently includes the following thirteen types of rubber: acrylic, butyl, nitrile, SBR (butadiene-styrene), Hypalon, Kel-F, fluoro-silicone, natural, Neoprene, silicone, Thiokol, urethane, and Viton-A. These rubbers were formulated, compounded, and processed from the raw polymer to the finished product by the Rubber & Plastics Section, and were molded in two shapes, o-rings and flat gaskets. The plastic materials included in the test were nylon, Teflon, and two forms of Kel-F (plasticized and unplasticized). The plastic materials were tested as flat gaskets only. Included in the initial program were the following commercial gaskets: rubber o-rings, Toruseal metal o-rings, Flexitallic, and Allpax.

New rubber and plastic materials are continually under development, and improved compositions of the thirteen types of rubber are under constant study in the laboratory. Each of these new and improved materials must be thoroughly evaluated before its reliability as a gasket material can be ascertained.

Gainesville, Florida and MSFC were selected as sites for the installed aging tests. Atmospheric conditions characteristically described for these two sites are semi-tropical and temperate zone climates, respectively. Effective July 1, 1958, an R&D contract was let to the University of Florida at Gainesville. Under this contract, the University supplied the necessary space, building, personnel assistance, and minor supplies needed for the program.

The installed gaskets were pressure tested semi-annually according to the procedures outlined in Appendix C. The gaskets which failed the test were removed, and new or improved materials were installed in the test fixture. Accelerated laboratory aging by ozone, air bomb techniques, and compression set studies were used to determine the relative age resistance of the several types of rubber, and the results obtained by these methods are of technical interest. Outdoor weather tests were also made on all of the rubber compounds. Careful physical testing, before and after aging, was an important phase of this program. These tests were used to measure progress made in the development of improved age-resistant stocks. As data are accumulated in the aging program, correlations between laboratory data and service life of the gasket materials will be attempted.

## MATERIALS

### A. RUBBER GASKETS

In the initial phase of the program, o-ring and flat gaskets of the following types of rubbers were installed in component vehicle

hardware: Neoprene, fluorosilicone, nitrile, natural, silicone, butyl, and Viton-A. SBR (butadiene-styrene) rubber was also installed in test fixtures as o-rings only. Since then, the program has been expanded to include o-ring and flat gaskets of Kel-F, Hypalon, acrylic, Thiokol, urethane, and improved formulations of acrylic, Hypalon, fluorosilicone silicone, and nitrile rubbers. The thirteen different elastomers, source of base polymers, and chemical composition are listed in Appendix A, Table 1. Physical properties of the elastomers under test are contained in Appendix A, Table 2. The gaskets were molded from 70 Shore-A hardness rubbers [except for fluorosilicone (LS-53) gaskets which were 60 hardness]7.

In October, 1961, a new gasket test was initiated. All thirteen rubbers were installed as flat and o-ring gaskets for single tests at three pressures. No lubricant was used on any of the gaskets. The flat gaskets were tested at 200, 400, and 800 psi, and had a minimum thickness of 0.060". The o-rings were tested at 250, 500, and 1000 psi, and had cross-sectional diameters of .138" to .143". Both types of gaskets were carefully selected and measured for fit and tolerances.

#### B. PLASTIC GASKETS

Flat gaskets from nylon, Teflon, and plasticized and unplasticized Kel-F were included in the initial program. The source and chemical composition of these types of plastics are also listed in Appendix A, Table 1.

#### C. COMMERCIAL GASKETS

Four types of commercial gaskets (rubber o-rings, metal o-rings, Flexitallic, and Allpax) were installed in bolted flange and Marman type hardware. The rubber o-rings were typical commercial products conforming to military specifications MIL-P-5315, MIL-G-5510, and MIL-P-5516. The Toruseal metal o-rings were made from type 321 stainless steel. The Flexitallic gaskets were made from a spirally wound ribbon of type 301 or 304 stainless steel interleaved with asbestos tape.

### TEST FIXTURES

Detailed drawings for the various types of test fixtures (flanges and valves) used to contain the gaskets are shown in Appendix B, drawings MR-73-1 thru MR-73-11. The various bolted type flanges are shown in drawings MR-73-1 thru MR-73-6. Drawing MR-73-5 (stainless steel) and MR-73-6 (aluminum) contain a diaphragm separation plate and two o-ring gaskets per fixture. In some cases, the drawing number designates a type of fixture that is common to more than one type of gasket. For example, in drawing MR-73-2, FIG. 2A is for a Flexitallic gasket, FIG. 2B for an o-ring, FIG. 2C for Allpax and flat gaskets, and FIG. 2D for flat gaskets. Drawing MR-73-3 is essentially the same as MR-73-2 except that the flanges are made of stainless steel instead of aluminum.



Drawing MR-73-7 shows a Marman flange constructed of 6061 aluminum. In this drawing, FIG. 7A is for o-ring, FIG. 7B for a stainless steel o-ring, and FIG. 7C for a Flexitallic gasket. Drawing MR-73-8 shows a Marman flange designed specifically for determining the effect of galvanic corrosion of dissimilar metals, aluminum and stainless steel.

Three types of solenoid valves, MV-76, MV-74, and LOX replenishing valve, are shown in drawings MR-73-9 thru MR-73-11 respectively. The MV-74 and MV-76 valves contain dynamic and static o-ring gaskets, and their purpose in this program was intended to demonstrate dynamic gasketing as a function of installed life. MV-74 and MV-76 valves are produced commercially. The LOX replenishing valve is an MSFC designed and fabricated item, and contains one dynamic Teflon seal, five static rubber o-ring gaskets, and two Flexitallic gaskets.

In the new study begun October, 1961, flat and o-ring bolted fixtures were used which met more rigid specifications than those used heretofore. The surface waviness was reduced and a finer finish was specified at the sealing surfaces. The depth of the o-ring groove was held at 0.109"  $\pm$  .003" in order to increase the gasket compression to about 20%. All of the fixtures were measured and carefully examined for defects.

#### A. TEST LOCATIONS

Duplicate tests are in progress at Gainesville, Florida and Marshall Space Flight Center. Under contract (NAS8-1523) with the University of Florida, the exposure building, personnel assistance, and minor supplies were provided. The exposure site is situated approximately ten miles from Gainesville, adjacent to the Municipal Airport. The building was designed to protect the test fixtures against direct exposure to the elements, but otherwise allows them to be exposed to the prevailing ambient atmospheric conditions. A photograph of this structure is shown in Appendix D, FIG. 1.

#### B. INSTALLATION OF GASKETS IN TEST FIXTURES

Gaskets were examined for defects and installed in the appropriate test fixture. No lubricants were used with the flat rubber and plastic gaskets. Compatible lubricants were used with o-ring gaskets. The lubricants used with the different gaskets are listed in Appendix A, Table 3. Each gasket was placed in a bolted flange fixture and torque pressures applied, as listed in Appendix A, Table 3. A photograph of the final stage of a gasket installation in a bolted flange fixture is shown in Appendix D, FIG. 2. The installed gaskets were tested for leaks by standard procedures, and the test fixtures were placed on the test panels.

#### C. PANEL DESCRIPTION

Twelve 4' x 8' x 3/4" plywood panels were originally installed at each of the test sites. The test fixtures containing the gasket mate-

rials were numbered and mounted in the corresponding section of the panel. A photograph of a typical panel with mounted test fixture is shown in Appendix D, FIG. 3. Several panels located at MSFC are shown in a photograph in Appendix D, FIG. 4. As a result of the addition of eight new panels in October, 1961, twenty panels containing three hundred and one specimens are currently in the program.

## TEST PROCEDURES AND RESULTS

Rubber materials used in the gasket aging program were evaluated in the Ozone Test Chamber, air bomb, compression set test, and outdoor weathering. These tests were used to measure the progress made in the development of improved age resistant stocks.

### A. ACCELERATED OZONE TEST

Standard dumbbell specimens were tested in duplicate at 25 parts per hundred million (pphm) of ozone concentration for 0, 4, 8, 24 and 48 hours at ambient temperature in a Mast Ozometer, according to ASTM Method D-1149-55T. The procedure permitted dynamic cycling at the rate of 30 cycles per minute and 25% specimen elongation. The results of the 48-hour test are presented in Appendix A, Table 4. A photograph of the Mast Ozone Test Chamber is shown in Appendix D, FIG. 5. Examples of ozone cracks in natural rubber are shown in Appendix D, FIG. 6. The data show that the properties of natural, nitrile, and SBR rubbers were adversely affected by 25 pphm ozone in 48 hours.

Some of the rubbers which were more resistant to ozone attack were tested at 100 and 500 pphm ozone concentration for 1000 hours at ambient temperature. The rubbers tested at these ozone concentrations were:

<u>100 PPHM Ozone</u>	<u>500 PPHM Ozone</u>
Neoprene	Acrylic
Kel-F	Kel-F
Fluorosilicone	Fluorosilicone
Silicone	Silicone
Urethane	Urethane
Viton-A	Viton-A

Ozone cracks appeared in the Neoprene samples after 48 hours in 100 pphm ozone, and the properties of this rubber were seriously affected in 168 hours exposure. All other rubbers listed above were unaffected by 100-500 pphm of ozone for 1000 hours at room temperature. The results of the 1000-hour tests at 100 and 500 pphm ozone concentration are presented in Appendix A, Tables 5 and 6, respectively.

## B. AIR BOMB ACCELERATED TEST

The rubber samples were tested in the air bomb according to ASTM Procedure D 454-53. In this test, standard dumbbell specimens (in triplicates) were placed in a steam-heated autoclave. The samples were tested at 127°C and 80 psi air pressure for 0, 4, 8, 24 and 48 hours. The results of the 48-hour tests are recorded in Appendix A, Table 7. An examination of these results showed that the butyl, nitrile (RA-22370BN), SBR, natural, and Thiokol rubbers were adversely affected by the air bomb tests. An improved nitrile rubber (RA-30870BN) and all of the other materials met the required specifications. A photograph of the air bomb apparatus and examples of test specimens are shown in Appendix D, FIG. 7.

## C. COMPRESSION SET OF VULCANIZED RUBBERS - METHOD B

The accelerated compression set property of vulcanized rubber was determined according to ASTM Method D 395-55, Method B. Compression set tests measure the ability of a rubber compound to resist permanent deformation due to compressive stressing at stated temperatures and time of compression. The results are expressed as a percentage of the original deflection as determined from the initial and final thickness of the specimen. (See Appendix A, Table 8.)

Reference to the table cited above shows that compression set test results are somewhat dependent on the temperature at which the tests are made.

## D. OUTDOOR WEATHERING

The effects of normal weathering at MSFC on rubber samples were determined according to ASTM Procedure D 518-57T, Part B. In this test, duplicate looped specimens, having varying degrees of elongation along the length of the loop, were exposed to weather and sunlight at an angle of 45 degrees facing south (see Appendix D, FIG. 8). The samples were examined periodically (daily initially, and later, weekly) for the appearance of surface cracks by which failure is indicated. The results of the outdoor weathering tests are presented in Appendix A, Table 9. The effects of outdoor weathering and resulting surface cracks on natural rubber samples are shown in Appendix D, FIG. 9.

Specimens of natural rubber exposed to outdoor weathering produced cracks in seven hours, in three days for SBR rubber, and in eight days for Nitrile rubber. Butyl rubber lasted seven months, and Neoprene failed in fifteen months. Although the data are incomplete, the results show that fluorosilicone, silicone, and Viton-A rubbers are much less adversely affected by weather and sunlight than is Neoprene.

#### E. INSTALLED GASKET TESTING

Each gasket was tested for leaks at the time of installation, and pressure tested subsequently every six months. Measurable leakage rates at any test period were recorded so as to provide a running history of each gasket. When the leakage rate became greater than allowed by the tolerance stated below, failure was indicated.

The leak test consisted of applying gas pressure to the test fixture, according to procedures outlined in Appendix C. Each assembly was equipped with an AN-815-4 fitting to facilitate pressurization of the fixture (see drawing, Appendix B). Compressed nitrogen gas was used to pressurize the test fixture by means of the pressure control panel shown in Appendix D, FIG. 10. Each installed gasket was pressure tested at the test pressures listed in Appendix A, Tables 10 thru 17. Leakage rates were measured by collecting the escaping gas in a graduated cylinder by water displacement for a specific time interval as illustrated in Appendix D, FIG. 10. Allowable leakage rates for all static seals (except thrust chamber seals) are defined as follows:

1. Leaks less than 1 cc/min. are disregarded.
2. Leaks of 1-10 cc/min. are recorded, but do not constitute failure.
3. Leaks in excess of 10 cc/min. constitute failure of the gasket to seal adequately.

The allowed leakage rate for thrust chamber seals was 410 ml/min. The leakage rates allowed for the solenoid actuated valves were:

1. MV-74-(gas) valve - 160 cc/min.
2. MV-76-(gas) valve - 80 cc/min.
3. LOX replenishing valve - Main valve - 160 cc/min.  
Control valve - 160 cc/min.

With the LOX valve, the control valve was tested at 750 psi and the main valve at 40 psi.

When a test showed that an installed gasket was leaking in excess of the allowed leakage rate at either of the test sites, pressure testing was discontinued for that gasket. When two out of three gaskets failed the leakage tolerances, all three gaskets were removed. The test fixtures then became available for new material. If failure occurred at one site, the test was continued at the other location until failure was indicated.

Testing and evaluation of the results at MSFC or Gainesville were independent of each other, even though identical materials were tested at both locations.

#### F. INSTALLED GASKET AGING TEST RESULTS

The results, for the period of this report, of the installed rubber, plastic, and commercial gaskets at MSFC and Gainesville are presented in Appendix A, Tables 10 thru 15. Additional information relating to the gaskets, test fixtures, and test conditions is also given in these tables.

The data show a few individual specimen failures of domestic rubber gaskets over the test period of two and one-half years, and these failures occurred primarily in dynamic seals. One of the SBR rubber o-ring gaskets failed the 750 psi pressure test at the time of installation and was disqualified as a valid test specimen. The second SBR o-ring failed after six months of installed life. The third SBR specimen had not failed after two years of aging; therefore, the failure for SBR type of rubber, due to aging, as defined in this report, had not yet occurred. Duplicate tests in Florida show the SBR gaskets to be sealing adequately. One of three MV-76 valves fitted with fluorosilicone (LS-53) o-rings and tested at MSFC leaked excessively after one and one-half years on test. One of the three MV-74 valves, containing three dynamic and eight static Viton o-ring seals per valve, failed during the first six months of installed life. All o-rings in this valve were replaced with a new set. The other two valves containing the original Viton o-rings continue under test and did not show any signs of failure at the last test period (October, 1961). Neoprene gaskets in one of three MV-74 valves at MSFC failed after two years on test. One of two MV-76 valves containing Thiokol rubber gaskets, at Gainesville, failed after six months on test.

The results show that all the flat plastic gaskets are sealing adequately at MSFC and Florida during the first two years of test.

No failures occurred with the commercial rubber o-ring gaskets over test periods ranging from two years (MSFC) to two and one-half years (Gainesville). However, one MV-74 valve leaked after two years at MSFC, but this did not constitute failure as defined. As previously defined, failure required that two out of three gaskets leak in excess of allowable tolerances.

LOX valves containing Teflon dynamic seals failed after two years (Gainesville). No failures were attributed to the several commercial rubber o-ring gaskets contained in the valve as static seals. There was no duplication of LOX valves with commercial gaskets at MSFC.

Two of the three Allpax gaskets failed at MSFC when tested initially at 500 psi. Duplicate gaskets at Gainesville failed after two years on test. Allpax gaskets tested at 50 and 225 psi pressure at both locations are sealing adequately after two years on test.

Six out of six Flexitallic gaskets in aluminum fixtures (MR-73-6A) failed at 750 psi pressure in six months at MSFC and in one year in Florida. In stainless steel fixtures (MR-73-5A), two out of three Flexitallic

gaskets failed after one and one-half years.

The results of initial pressure testing of 78 new gaskets added (October, 1961) at MSFC and Gainesville are recorded in Appendix A, Tables 16 and 17. Difficulties were encountered in getting SBR rubber o-rings to pass the 1000 psi pressure test at Gainesville, and no gasket is currently under test at that pressure level.

## DISCUSSION OF RESULTS

### A. THEORY OF AGING IN ELASTOMERS

It would be impractical, in the scope of this report, to attempt a detailed explanation of the effect of oxygen and ozone aging for each of the thirteen elastomers under study. While this would be a worthy goal to accomplish, this would require much study of previously published works and laboratory experimentation. The urgency and complexity of getting the program to its present status has not permitted this study and experimentation, and all that shall be attempted here is to review the currently acceptable basic concepts of crosslinking and scission processes in high polymers.

Manufactured rubber products begin to degrade immediately after vulcanization, and aging continues in storage, or service, until the products are no longer suitable for their intended use. Physical deterioration occurs through abuse of the product in handling and through the swelling and subsequent weakening of the rubber by solvents, fuels, chemicals, etc.

Chemical changes in vulcanized rubber that take place with aging are probably due to three reactions, all proceeding simultaneously to a greater or lesser extent:(1)\*

1. Chain scission occurs in the long molecular chains (or in the crosslinks) which form the major structure of these so-called linear polymers.

2. Crosslinking linear molecular chains to form three dimensional molecules.

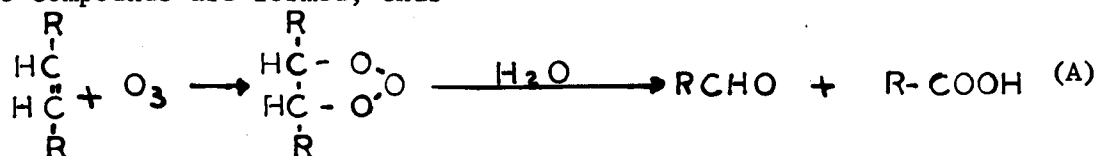
3. Modification of side groups.

If chain scission occurs, the average molecular weight of the polymer is reduced, resulting in a loss of tensile strength. Crosslinking decreases the elongation, but increases the stiffness of the polymer. Modification of the side groups normally has little effect on tensile properties, but may alter such properties as solvent resistance and electrical qualities.

\*Superscripts refer to references.

The aging of elastomeric materials is influenced by environment. Thus, crosslinking of molecules may be induced in some cases under the influence of heat or light in the complete absence of other chemicals. Deterioration is caused by excessive heat and/or chemical reaction with the environment, usually ozone and oxygen. Moisture undoubtedly plays a part in these reactions, but its role is probably more catalytic than as a reactant, especially where fungus-induced deterioration is present.

Ozone is a powerful reagent for attacking carbon-to-carbon double bonds, by forming an ozonide, which subsequently decomposes to cause severance of the original bond. When such a reaction takes place in a linear polymer molecule, chain scission is said to occur (2)(3)(4). By decomposition of the ozonide in the presence of water, aldehydes and acidic compounds are formed, thus -



Some of the factors affecting the attack of rubber products by ozone are (5):

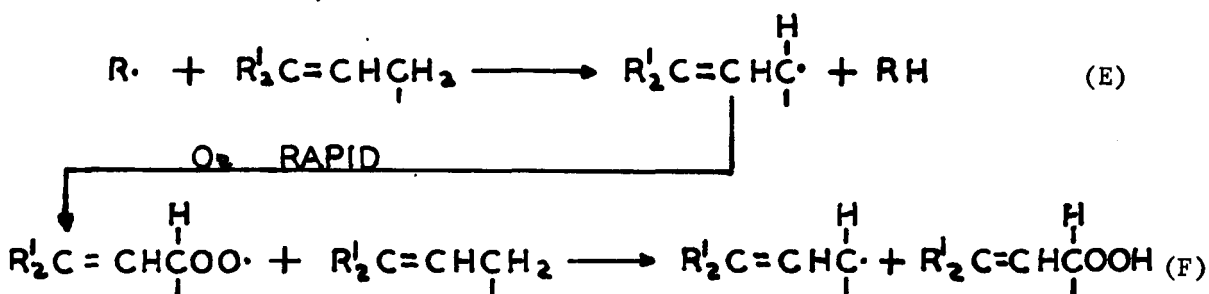
1. Ozone concentration.
2. Residual unsaturation.
3. Stress on specimen - dynamic or static.
4. Chemical nature of base polymer.
5. Compounding variables such as the presence of antiozonants, antioxidants, the type and quantity of filler, plasticizer content, etc.
6. Exposure temperature.
7. State of cure.

Chemically saturated types of elastomers (except Thiokol polysulfide rubbers) are inherently resistant to ozone attack. It is probable that the resistance that Neoprene offers to ozone attack is attributable to steric hindrance resulting from the presence of chlorine on the methylenic carbon atom (6).

The degradation of elastomers by oxygen proceeds through a free-radical chain reaction and may cause either chain scission or crosslinking (1). Free radicals (indicated by ".") are produced from unstable groups by energy from heat or light. The free radicals react with oxygen to form peroxidic radicals which in turn extract hydrogen from some other molecule to form a hydroperoxide and another free radical. The hydroperoxides are relatively unstable and slowly decompose into free radicals which initiate new chains. Ideally, this process is illustrated by the following general reactions:

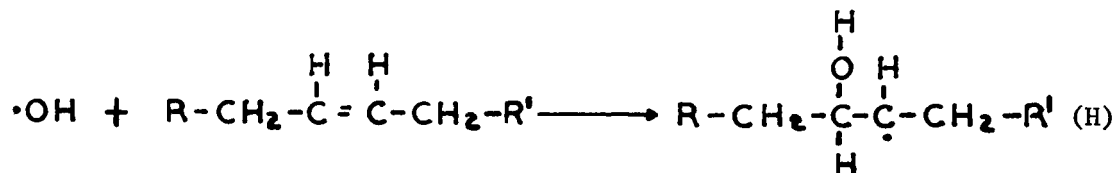
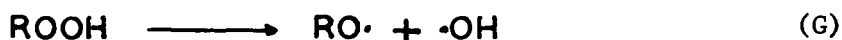


Similarly, reported evidence (9) indicates that free radicals extract hydrogen from the alpha-methylene carbon atom (relative to a double bond), which then adds oxygen rapidly to form a hydroperoxide and another free radical, thus

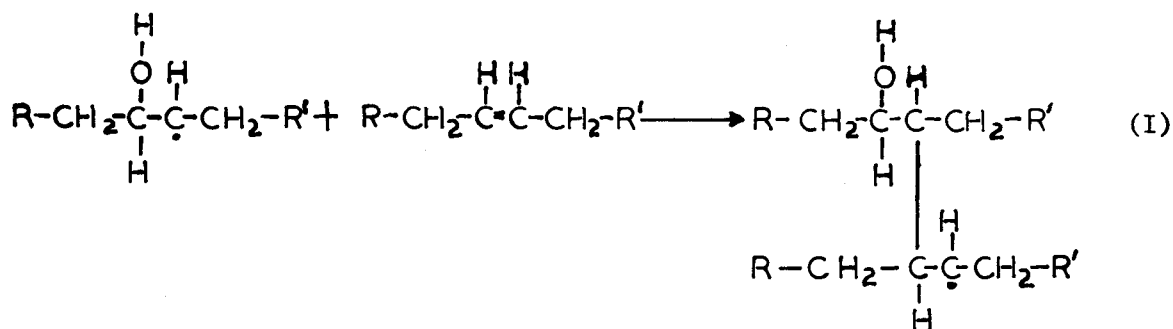


This process, once started, proceeds more or less automatically so long as an active hydrogen atom is present on the carbon atom alpha to a double bond, resulting in chain scission. Complications in this scheme are introduced by changes in the olefin structure such as the presence of a neighboring double bond (10). Cleavage of the sulfur bridges, in rubber compounds so vulcanized, may also take place by the action of oxygen. However, most of the experimental data indicate that crosslink scission, if it occurs, is of minor significance compared with random cutting of the C-C chain (9).

Crosslinking of unsaturated compounds also results from oxidation and is usually the dominant reaction with Neoprene, SBR, and nitrile rubbers. Either  $R\cdot$ ,  $RO\cdot$ ,  $ROO\cdot$ , or  $\cdot OH$  can add to a double bond to initiate polymerization by a free-radical mechanism (1)(8)(11). The crosslinking reaction is not just a simple polymerization of the olefins as the rate in the absence of oxygen is extremely slow. A typical sequence of this reaction may be illustrated as follows:







The new radical can react with another radical, or with oxygen, to form another peroxide group, or with a double bond in another chain to form an additional crosslink.

The reactions of ozone and oxygen are primarily at the points of unsaturation in elastomeric materials. The results of the accelerated ozone, air bomb, and the outdoor weathering tests for the thirteen different rubbers are in general agreement with this conclusion. The results presented in Appendix A, Table 4 show that the properties of natural, nitrile, and SBR rubbers were adversely affected by 25 pphm ozone after 48 hours at room temperature. These rubbers, excluding Neoprene, have the highest degrees of unsaturation, and the loss of tensile strength in these elastomers is undoubtedly due to chain scission at the double bond caused by ozone attack. Under these test conditions, the tensile strengths of butyl and Neoprene rubbers were not appreciably affected. Butyl rubber has much less unsaturation than natural, nitrile, and SBR rubbers and, accordingly, it is not as readily attacked by ozone. The resistance of Neoprene to ozone attack is thought to be due to deactivation of the double bond by the adjacent chlorine atom. The other eight elastomeric materials contain few, if any, points of unsaturation and were not appreciably affected by ozone at this concentration.

#### B. ACCELERATED AGING TEST RESULTS

The results presented in Appendix A, Table 6 show that the tensile properties of six of the elastomers (saturated type) were not appreciably affected by 500 pphm ozone for 1000 hours at room temperature. The tensile property of Neoprene was adversely affected by 100 pphm ozone (see Appendix A, Table 5). Although the adjacent chlorine atom deactivates the double bond to some extent (probably by steric hindrance), these tests clearly show that unsaturated elastomers are attacked by ozone and saturated elastomers are generally more resistant.

The outdoor weathering tests on the same stocks (see Appendix A, Table 9), although incomplete at this writing, agree with the results of

the accelerated ozone tests. Natural, nitrile, and SBR rubbers failed the test in a few days. The butyl rubber samples failed in seven months, and the Neoprene samples in fifteen months. None of the saturated elastomeric materials have failed yet and, accordingly, show greater resistance to ozone attack.

Rubber samples in the air bomb test are exposed both to oxygen and to heat. The tensile strengths of butyl, one of the nitriles, SBR, natural, and Thiokol rubbers were seriously affected by this test (see Appendix A, Table 7). The loss in tensile strength, except for Thiokol, was probably caused by chain scission resulting from the decomposition of hydroperoxide groups, associated with a double bond, at the elevated temperature of the test. Chain scission in the Thiokol rubber is probably caused from oxygen attacking the polysulfide linkage. Oxygen causes crosslinking of the polymer chains as well as chain scission. The decrease in elongation of the nitrile and Neoprene rubbers, and to a lesser extent the SBR rubbers, was caused by crosslinking of the polymers. The properties of the other seven (excluding Thiokol) saturated elastomers were not appreciably affected by this test. However, as the temperature is increased, the reaction kinetics favor an increased probability of chain scission at the weaker linkages, and at higher temperatures, the properties of the seven saturated elastomers would be seriously affected.

### CONCLUSIONS

The installed gasket aging program has not been in progress long enough to establish a general trend of failures of gasketing materials.

Domestically processed rubber gaskets have satisfactorily passed pressure testing after aging for two and one-half years. However, preliminary test data suggest that SBR rubber is an inferior gasketing material.

Commercial o-ring gaskets (nitrile rubber) have also satisfactorily passed pressure testing to date.

Flexitallic gaskets, tested at 75 and 200 psi pressures in bolted flange fixtures, were sealing adequately after two years on test. Flexitallic gaskets failed the 750 psi pressure test and are not recommended for use at that pressure with the type of flanges used in these tests.

Allpax gaskets failed the 500 psi pressure test and are not recommended for use at that pressure with the type of fixtures used in these tests. Allpax gaskets, tested at 50 and 225 psi pressure, are sealing adequately after two years on test.

Toruseal (321 Stainless) metal o-rings tested two years at MSFC and two and one-half years at Gainesville have not leaked at 100 psi test pressures.

No signs of galvanic corrosion nor gasket failures were found in Marman flanges consisting of dissimilar metals (6061-T6 anodized aluminum and 321 stainless steel) containing Flexitallic, metal (Toruseal) o-ring, and rubber o-ring gaskets.

None of the plastic (Teflon, nylon, plasticized and unplasticized Kel-F) gaskets failed during two years of exposure when tested at 225 psi pressure.

Laboratory tests were used to determine when new elastomeric materials were developed which had improved compression set properties and better resistance to ozone and oxygen attack. Improved compositions were developed in the laboratory from acrylic, nitrile, Hypalon and fluoro-silicone elastomers and were added to the program. The development of improved vulcanizable compounds and the testing of new polymers are an important and continuing phase of activity in the aging program.

Aging tests on installed gaskets must be continued for the development of high reliability in polymeric materials for use in rocket vehicles.

## APPENDIX A

TABLE 1  
RUBBER AND PLASTIC GASKET MATERIALS

Polymeric Gasket Materials	Composition	Manufacturer of Raw Materials
Rubber		
Acrylic	Copolymer of acrylic acid ester and a Halogen-containing derivative	B. F. Goodrich Chemical Company
Butyl	Copolymer of Isobutylene with small amount of Isoprene	Enjay Company, Inc.
Fluorosilicone	Fluorosilicone	Dow Corning Corporation
Hypalon	Chlorosulfonated Polyethylene	E. I. du Pont de Nemours & Company
Kel-F	Chlorotrifluoroethylene-vinylidene fluoride copolymer	Minnesota Mining & Manufacturing Company
Natural	Polyisoprene	-----
Neoprene	Polychloroprene	E. I. du Pont de Nemours & Company
Nitrile	Butadiene-Acrylonitrile Copolymer	B. F. Goodrich Chemical Company and Naugatuck Chemical Div., U. S. Rubber Company
SBR	Styrene-Butadiene Copolymer	-----
Silicone	Silicone	Linde Co. and General Electric Co.
Thiokol	Polysulfide	Thiokol Chemical Corporation
Urethane	Polyurethane	General Tire & Rubber Company
Viton-A	Vinylidene Fluoride-Hexafluoropropylene Copolymer	E. I. du Pont de Nemours & Company
Plastic		
Nylon	Poly-Hexamethylene-Adipamide	E. I. du Pont de Nemours & Company
Teflon	Poly-Tetrafluoroethylene	E. I. du Pont de Nemours & Company
Kel-F	Poly-chlorotrifluoroethylene	Minnesota Mining & Manufacturing Company

TABLE 2  
TYPICAL PHYSICAL PROPERTIES OF DIFFERENT RUBBERS

Rubber	Sample Designation	Hardness Shore-A	Resilience (Bashore) % Rebound	Specific Gravity	Tensile psi	Elongation %	Tear lbs./in.	Modulus, psi					
								100%	200%	300%	400%	500%	600%
Acrylic	RA-31170A	70	6	1.27	1400	240	130	500	1100				
"	RA-32570A	70	5	1.30	1375	230	120	400	1050				
Butyl	RA-25770B	70	8	1.15	2300	240	130	450	1650				
Fluoro-Silicone	LS-53	60	35	1.42	750	175	55	350					
"	RA-27870LS	70	32	1.47	700	160	60	400					
Hypalon	RA-30070H	70	10	1.41	1500	180	85	400					
"	RA-32970H	70	12	1.50	2500	270	150	450	1400				
Kel-F	RA-27170KF	70	5	2.08	4000	350	200	800	1800	3300			
Natural	RA-23070N	70	45	1.20	2700	450	270	500	1100	1800	2300		
Neoprene	RA-24270NE	70	31	1.44	3300	340	250	500	1500	2800			
Nitrile	RA-22370BN	70	8	1.27	2400	430	240	440	1250	2000	2300		
"	RA-30870BN	70	5	1.22	2400	650	220	330	700	1100	1400	1800	2200
SBR	RA-20770BS	70	35	1.20	3700	475	250	400	1000	2000	3100		
Silicone	RA-25170SI	70	46	1.18	750	150	70	440					
"	RA-28670SI	70	35	1.35	700	125	50	600					
Thiokol	RA-31970T	70	30	1.46	1050	200	60	450					
Urethane	RA-33370U	70	46	1.34	4200	360	375	550	2200	3700			
Viton-A	RA-26470VA	70	5	2.35	1900	150	135	900					

TABLE 3  
TEST ASSEMBLY TORQUE PRESSURES AND LUBRICANTS EMPLOYED ON GASKETS

Gasket Material	Gasket Lubricant	Assembly Torque (in. lbs.)	Drawing Number
<u>Bolted Flat Gaskets</u>			
All Rubber <sup>(1)</sup>	None	250-300	MR-73-2C & 2D
All Plastic	None	300	MR-73-2C
Allpax	Molykote Z	300	MR-73-2C & 2D
Allpax	Molykote Z	190	MR-73-3C
Flexitallic	Molykote Z	300	MR-73-2A
Flexitallic	Molykote Z	190	MR-73-3A
Flexitallic	LOX Lube	260	MR-73-5A & 6A
<u>Bolted O-Ring Gaskets</u>			
Commercial Rubbers	MIL-L-6032	190	MR-73-2B & 3B
Nitrile (RA-22370BN)	MIL-G-3278A	190	MR-73-2B
Butyl, Fluorosilicone (LS-53), Neoprene, and Viton-A Rubbers	MIL-L-4343	190	MR-73-2B
Fluorosilicone Hypalon and Kel-F Rubbers	MIL-L-4343A	190	MR-73-2B
Nitrile (RA-30870BN), Thiokol and Urethane Rubbers	MIL-L-4343A	260	MR-73-4A
Commercial and Natural Rubbers	MIL-L-6032	260	MR-73-6B
SBR Rubber	MIL-L-4343	260	MR-73-6B
Acrylic and Hypalon Rubbers	MIL-4343A	260	MR-73-6B
Silicone Rubber	Quaker State Wheel Bearing	260	MR-73-6B
Commercial, Fluorosilicone (LS-53), and Viton-A rubbers	MIL-L-4343	160-190	MR-73-1
13 Different types of Rubber	None	250	MR-73-4B
<u>Marman Fixtures</u>			
Commercial Rubbers	MIL-L-6032	70	MR-73-7A & 8A
Butyl, Fluorosilicone (LS-53), Neoprene and Viton-A Rubbers	MIL-L-4343	70	MR-73-8A
Fluorosilicone Hypalon and Kel-F Rubber	MIL-L-4343A	70	MR-73-8A
Nitrile (RA-22370BN) Rubber	MIL-G-3278A	70	MR-73-8A
Toruseal Metal	Molykote Z	70	MR-73-7B & 8B
Flexitallic	Molykote Z	70	MR-73-7C
Flexitallic	Molykote Z	70	MR-73-8C

(1) In the study on the effect of pressure on the aging of installed rubber gaskets (MR-73-2D), a torque of 250 in. lbs. was used. For all other flat gaskets, a torque of 300 in. lbs. was used.

TABLE 4

EFFECT OF 25 PPHM\* OZONE ON RUBBER SAMPLES  
 TEST CONDITIONS: TEMPERATURE-AMBIENT  
 TIME -48 HOURS

Rubber	Sample Designation	Initial Properties		Properties After 48-Hour Test				Remarks
		Tensile psi	Elongation %	Tensile psi	Elongation %	% Retained		
						Tensile	Elongation	
Acrylic	RA-31170A	1867	388	1884	355	101	92	No visible cracks
Butyl	RA-25770B	2500	365	2460	325	98	89	" "
Fluoro-Silicone	RA-27870LS	966	177	939	143	97	81	" "
Hypalon	RA-30070H	1867	235	2005	250	107	106	" "
Hypalon	RA-32970H	1992	163	2240	193	112	118	" "
Kel-F	RA-27170KF	3933	440	3943	410	101	93	" "
Natural	RA-23070N	2888	525	1505	325	52	62	Visible cracks in 4 hrs.
Neoprene	RA-24270NE	3542	325	3246	303	92	93	No visible cracks
Nitrile	RA-22370BN	2528	393	1866	235	74	60	Visible cracks in 24 hrs.
Nitrile	RA-30870BN	2880	730	1983	610	69	83	Visible cracks in 8 hrs.
SBR	RA-20770BS	3903	512	2060	410	53	80	Visible cracks in 8 hrs.
Silicone	RA-25170SI	762	117	799	115	105	99	No visible cracks
Silicone	RA-28670SI	718	132	640	135	89	102	" "
Thiokol	RA-31970T	1077	203	971	150	90	74	" "
Urethane	RA-33370U	4094	355	4316	367	106	103	" "
Viton-A	RA-26470VA	1658	165	1860	218	112	132	" "

\*PPHM = Parts Per Hundred Million

TABLE 5

EFFECT OF 100 PPHM\* OZONE ON RUBBER SAMPLES  
 TEST CONDITIONS: TEMPERATURE-AMBIENT  
 TIME -1000 HOURS

Rubber	Sample Designation	Initial Properties		Properties After 1000-Hour Test			Remarks
		Tensile psi	Elongation %	Tensile psi	Elongation %	% Retained Tensile    Elongation	
Fluoro-Silicone	RA-27870LS	1020	147	988	125	97    85	No visible cracks
Kel-F	RA-27170KF	3928	378	3488	325	89    86	"    "
Neoprene	RA-24270NE	3446	260	758**	118**	22    45	Visible cracks in 48 hrs.
Silicone	RA-28670SI	772	115	712	110	92    96	No visible cracks
Urethane	RA-35670U	4822	853	4860	823	101    97	"    "
Viton-A	RA-26470VA	1734	160	1748	125	101    78	"    "

\* PPHM = Parts Per Hundred Million

\*\*Exposed Only 168 Hours



TABLE 6  
EFFECT OF 500 PPHM\* OZONE ON RUBBER SAMPLES  
TEST CONDITIONS: TEMPERATURE-AMBIENT  
TIME -1000 HOURS

Rubber	Sample Designation	Initial Properties		Properties After 1000-Hour Test				Remarks
		Tensile psi	Elongation %	Tensile psi	Elongation %	% Retained		
						Tensile	Elongation	
Acrylic	RA-31170A	1780	383	1682	325	95	85	No visible cracks.
Fluoro-Silicone	RA-27870LS	1021	167	860**	130**	84	78	" "
Kel-F	RA-27170KF	4230	310	3998	275	95	89	" "
Silicone	RA-28670SI	815	120	734	110	90	92	" "
Urethane	RA-33370U	4375	395	3801	338	87	86	" "
Viton-A	RA-26470VA	1765	157	1662	148	94	94	" "

\*PPHM = Parts Per Hundred Million

\*\*Samples Broke at Clamp and Value Should Be Higher.

TABLE 7

AIR BOMB AGING OF SEVERAL TYPES OF RUBBER  
 TEST CONDITIONS: TEMPERATURE-127°C  
 TIME - 48 Hrs.  
 AIR PRESSURE-80 psi

Rubber	Sample Designation	Initial Properties		Properties After 48-Hour Test			
		Tensile psi	Elongation %	Tensile psi	Elongation %	Tensile psi	% Retained Elongation
Acrylic	RA-31170A	1867	388	1683	468	90	120
Butyl	RA-25770B	2500	365	1284	390	51	107
Fluoro-Silicone	LS-53	1044	211	817	282	78	134
Fluoro-Silicone	RA-27870LS	966	177	954	140	99	79
Hypalon	RA-30070H	1867	235	1900	225	102	96
Hypalon	RA-32970H	1992	163	1726	122	87	75
Kel-F	RA-27170KF	3933	440	4226	423	108	96
Natural	RA-23070N	2888	525	--*	-	-	-
Neoprene	RA-24270NE	3542	325	2761	163	78	50
Nitrile	RA-22370BN	2405	453	1752	111	73	25
Nitrile	RA-30870BN	2880	730	2387	295	83	40
SBR	RA-20770BS	3903	512	2242	193	57	38
Silicone	RA-25170SI	916	181	906	179	99	99
Silicone	RA-28670SI	718	132	956	163	133	123
Thiokol	RA-31970T	1077	203	10	185	1	91
Urethane	RA-33370U	4094	355	3233	372	79	105
Viton-A	RA-26470VA	1834	165	1707	163	93	99

\*No Strength After 48 Hours

TABLE 8

## COMPRESSION SET OF ELASTOMERS

Elastomers	Sample Designation	Percent Compression Set (1), 70 Hrs. @		Percent Compression Set (1), 140 Hrs @		
		50°C	100°C	150°C	50°C	100°C 150°C
Acrylic	RA-31170A	11	9	39	9	16 61
Acrylic	RA-32570A	11	9	33	12	13 52
Butyl	RA-25770B	10	72	--	12	76 --
Fluoro-Silicone	LS-53(2)	6	13	37	8	19 41
Fluoro-Silicone	RA-27870LS	8	13	35	9	16 44
Hypalon	RA-30070H	5	14	86	4	18 98
Hypalon	RA-32970H	5	15	73	5	25 96
Kel-F	RA-27170KF	40	49	74	40	50 79
Natural	RA-23070N	12	51	87	15	65 --
Neoprene	RA-24270NE	6	16	44	7	22 63
Nitrile	RA-22370BN	9	29	71	13	44 87
Nitrile	RA-30870BN	25	23	71	24	27 85
SBR	RA-20770BS	11	24	70	15	38 --
Silicone	RA-28670SI	6	10	13	7	10 16
Thiokol	RA-31970T	57	--	--	75	-- --
Urethane	RA-33370U	14	67	--	17	87 --
Viton-A	RA-26470VA	15	13	26	17	14 37

(1) Compression Set Expressed as a Percentage of the Original Deflection.

(2) About 60 Hardness (Shore-A). All the others are 70 Hardness.

TABLE 9

RESISTANCE OF RUBBER SAMPLE TO SURFACE CRACKING  
IN OUTDOOR WEATHERING AT MSFC  
(December, 1961)

Rubber	Sample Designation	Date Installed	Date Failed	Time Exposed
Acrylic	RA-31170A	15 Nov 60	-	13 Months
Butyl	RA-25770B	10 Feb 59	28 Sept 59	7 Months
Fluoro-Silicone	LS-53	10 Feb 59	-	34 Months
Fluoro-Silicone	RA-27870LS	15 Nov 60	-	13 Months
Hypalon	RA-30070H	14 Oct 60	-	14 Months
Hypalon	RA-32970H	20 Mar 61	-	9 Months
Kel-F	RA-27170KF	14 Oct 60	-	14 Months
Natural	RA-23070N	18 Oct 60	19 Oct 60	1 Day
Neoprene	RA-24270NE	10 Feb 59	15 May 60	15 Months
Nitrile	RA-22370BN	10 Feb 59	18 Feb 59	8 Days
Nitrile	RA-30870BN	14 Oct 60	26 Oct 60	12 Days
SBR	RA-20770BS	14 Oct 60	17 Oct 60	3 Days
Silicone	RA-25170SI	10 Feb 59	-	34 Months
Silicone	RA-28670SI	10 Feb 59	-	34 Months
Thiokol	RA-31970T	20 Mar 61	-	9 Months
Urethane	RA-33370U	8 Mar 61	-	9 Months
Viton-A	RA-26470VA	1 May 59	-	31 Months

TABLE 10  
AGING OF RUBBER GASKETS AT MSFC

GASKET				FIXTURES AND TEST CONDITIONS						RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Viton-A	RA-26470VA	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
"	"	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	8/59	-	2.0
"	"	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	8/59	-	2.0
"	"	"	0.210 X 19.5	Bolted	MR-73-1	750	3	410	1	2	151	8/59	-	2.0
"	"	"	0.070 X 0.145	Valve (MV-74)	MR-73-10	750	3(1)	160	2	0	0	8/59	-	2.0
"	"	"	0.070 X 0.364	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.072 X 0.351	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.103 X 0.612	"	"	"	"	"	"	"	"	"	"	"
Fluoro-Silicone	LS-53	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
"	"	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	8/59	-	2.0
"	"	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	8/59	-	2.0
"	"	"	0.210 X 19.5	Bolted	MR-73-1	750	3	410	1	1	1	8/59	-	2.0
"	"	"	0.069 X 0.070	Valve (MV-76)	MR-73-9	2000	3	80	3	1(2)	95	8/59	-	2.0
"	"	"	0.070 X 0.239	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.070 X 0.516	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.078 X 0.468	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.103 X 0.487	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.072 X 0.351	Valve (LOX)	MR-73-11	750/40	1	160/160	4	0	0	5/60	-	1.5
"	"	"	0.097 X 0.755	"	"	"	"	"	"	"	"	"	"	"
Fluoro-Silicone	RA-27870LS	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/60	-	1.0
"	"	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	2	10	1	0	0	9/60	-	1.0
"	"	"	0.139 X 3.359	Marman	MR-73-8A	100	2	10	1	0	0	9/60	-	1.0
Neoprene	RA-24270NE	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
"	"	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	8/59	-	2.0
"	"	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	8/59	-	2.0
"	"	"	0.070 X 0.145	Valve (MV-74)	MR-73-10	750	3	160	2	1	500	8/59	-	2.0
"	"	"	0.070 X 0.364	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.072 X 0.351	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.103 X 0.612	"	"	"	"	"	"	"	"	"	"	"

(1) Gaskets replaced in one valve 5/60.

(2) Failed 4/61.



TABLE 10 (CONT'D)  
AGING OF RUBBER GASKETS AT MSFC

GASKET				FIXTURES AND TEST CONDITIONS							RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test	
Hypalon	RA-30070H	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/60	-	1.0	
	"	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	9/60	-	1.0	
	"	"	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	9/60	-	1.0	
	"	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	9/60	-	1.0	
	RA-31170A	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/60	-	1.0	
	"	O-Ring	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	9/60	-	1.0	
Acrylic	"	"	0.069 X 0.070	Valve (MV-76)	MR-73-9	2000	2	80	3	0	0	9/60	-	1.0	
	"	"	0.070 X 0.239	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.070 X 0.516	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.078 X 0.468	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.103 X 0.487	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.103 X 0.487	"	"	"	"	"	"	"	"	"	"	"	
Thiokol	RA-31970T	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	225	3	10	1	0	0	4/61	-	0.5	
	"	O-Ring	0.139 X 4.609	Bolted	MR-73-4A	750	3	10	1	0	0	4/61	-	0.5	
	"	"	0.069 X 0.070	Valve (MV-76)	MR-73-9	2000	2	80	3	0	0	4/61	-	0.5	
	"	"	0.070 X 0.239	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.070 X 0.516	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.078 X 0.468	"	"	"	"	"	"	"	"	"	"	"	
Urethane	RA-33370U	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	225	3	10	1	0	0	4/61	-	0.5	
	"	O-Ring	0.139 X 4.609	Bolted	MR-73-4A	750	3	10	1	0	0	4/61	-	0.5	
	"	"	0.070 X 0.145	Valve (MV-74)	MR-73-10	750	2	160	2	0	0	4/61	-	0.5	
	"	"	0.070 X 0.364	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.072 X 0.351	"	"	"	"	"	"	"	"	"	"	"	
	"	"	0.103 X 0.612	"	"	"	"	"	"	"	"	"	"	"	
SBR	RA-20770BS	O-Ring	0.139 X 4.609	Bolted	MR-73-6B	750	2(3)	10	1	2	8	8/59	-	2.0	

(3) The third specimen failed at the time of installation and was disqualified as a valid test specimen. One valid specimen failed 4/60.

TABLE 11  
AGING OF PLASTIC GASKETS AT MSFC

GASKET					FIXTURES AND TEST CONDITIONS					RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Nylon	----	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
Teflon	----	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
Kel-F (Unplasticized)	----	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
Kel-F (Plasticized)	----	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0



TABLE 12  
AGING OF COMMERCIAL GASKETS AT MSFC

GASKET				FIXTURES AND TEST CONDITIONS						RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Rubber	MIL-P-5315	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	8/59	-	2.0
	MIL-P-5315	"	0.139 X 4.984	Bolted	MR-73-3B	100	3	10	1	0	0	8/59	-	2.0
	MIL-P-5315	"	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	8/59	-	2.0
	MIL-P-5315	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	8/59	-	2.0
	MIL-P-5315	"	0.139 X 3.359	Marman	MR-73-7A	100	3	10	1	0	0	8/59	-	2.0
	NA 2-4062	"	0.210 X 19.5	Bolted	MR-73-1	750	2	410	1	1	5	8/59	-	2.0
	(MIL-P-5315)	"	0.070 X 0.145	Valve (MW-74)	MR-73-10	750	3	160	2	1	330	8/59	-	2.0
	(MIL-C-5510)	"	0.070 X 0.364	"	"	"	"	"	"	"	"	"	"	"
	(MIL-P-5516)	"	0.072 X 0.351	"	"	"	"	"	"	"	"	"	"	"
	"	"	0.103 X 0.612	"	"	"	"	"	"	"	"	"	"	"
	"	"	0.069 X 0.070	Valve (MW-76)	MR-73-9	2000	3	80	3	0	0	8/59	-	2.0
	"	"	0.070 X 0.239	"	"	"	"	"	"	"	"	"	"	"
	"	"	0.070 X 0.516	"	"	"	"	"	"	"	"	"	"	"
Composition	"	"	0.078 X 0.468	"	"	"	"	"	"	"	"	"	"	"
	"	"	0.103 X 0.487	"	"	"	"	"	"	"	"	"	"	"
	Allpax SH-500	Flat	5.375 X 4.625 X .062	Bolted	MR-73-3C	50	3	10	1	0	0	8/59	-	2.0
	"	"	"	"	MR-73-2C	225	3	10	1	0	0	8/59	-	2.0
	"	"	"	"	MR-73-2D	225	3	10	1	0	0	10/59	-	2.0
	"	"	"	"	MR-73-2D	500	3	10	1	3(1)	12	8/59	10/59	0
	"	"	"	"	MR-73-2A	75	6	10	1	0	0	8/59	-	2.0
	"	"	"	"	MR-73-3A	200	3	10	1	2	2.5	8/59	-	2.0
	"	"	"	"	MR-73-6A	750	3	10	1	3	210	8/59	4/60	0.5
	"	"	"	"	MR-73-6A	750	3	10	1	3	700	5/60	9/60	0.5
Flexitalllic	304 SS-Asb.	Flat	5.218 X 4.778 X .125	"	MR-73-6A	750	3	10	1	3	115	8/59	4/60	0.5
	304 SS-Asb.	"	"	"	MR-73-6A	750	3	10	1	3	115	8/59	4/60	0.5
	301 SS-Asb.	"	"	"	MR-73-5A	750	3	10	1	2	14	8/59	4/61	1.5
	(2) AG 301Asb	"	"	"	MR-73-7C	75	3	10	1	0	0	8/59	-	2.0
	301 SS Asb.	"	"	"	MR-73-8C	225	6	10	1	0	0	8/59	-	2.0
	304 SS Asb.	"	3.968 X 3.520 X .125	Marman	MR-73-7B	100	3	10	1	0	0	8/59	-	2.0
Toruseal	321 SS	O-Ring	0.064 X 3.720	"	MR-73-8B	100	3	10	1	0	0	8/59	-	2.0
	"	"	"	"	"	"	"	"	"	"	"	"	"	"
	"	"	"	"	"	"	"	"	"	"	"	"	"	"

(1) Two failed when tested after installed.  
(2) This gasket was silver-coated 301 SS-Asbestos.





TABLE 13 (CONT'D)

## AGING OF RUBBER GASKETS AT GAINESVILLE, FLORIDA

GASKET				FIXTURES AND TEST CONDITIONS							RESULTS			
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Hypalon	RA-30070H	Flat	5.375 X 4.625 X .062	Bolted	MV-73-2C	225	3	10	1	0	0	9/60	-	1.0
"	"	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	9/60	-	1.0
"	"	"	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	9/60	-	1.0
"	"	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	9/60	-	1.0
Acrylic	RA-31170A	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/60	-	1.0
"	"	O-Ring	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	9/60	-	1.0
"	"	"	0.069 X 0.070	Valve (MV-76)	MR-73-9	2000	2	80	3	0	0	9/60	-	1.0
"	"	"	0.070 X 0.239	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.070 X 0.516	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.078 X 0.468	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.103 X 0.487	"	"	"	"	"	"	"	"	"	"	"
Thiokol	RA-31970T	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	225	3	10	1	0	0	4/61	-	0.5
"	"	O-Ring	0.139 X 4.609	Bolted	MR-73-4A	750	3	10	1	0	0	4/61	-	0.5
"	"	"	0.069 X 0.070	Valve (MV-76)	MR-73-9	2000	2	80	3	1	475	4/61	-	0.5
"	"	"	0.070 X 0.239	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.070 X 0.516	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.078 X 0.468	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.103 X 0.487	"	"	"	"	"	"	"	"	"	"	"
Urethane	RA-33370U	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	225	3	10	1	0	0	4/61	-	0.5
"	"	O-Ring	0.139 X 4.609	Bolted	MR-73-4A	750	3	10	1	0	0	4/61	-	0.5
"	"	"	0.070 X 0.145	Valve (MV-74)	MR-73-10	750	2	160	2	0	0	4/61	-	0.5
"	"	"	0.070 X 0.364	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.072 X 0.351	"	"	"	"	"	"	"	"	"	"	"
"	"	"	0.103 X 0.612	"	"	"	"	"	"	"	"	"	"	"
SBR	RA-20770BS	O-Ring	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	9/59	-	2.0

TABLE 14  
AGING OF PLASTIC GASKETS AT GAINESVILLE, FLORIDA

GASKET			FIXTURES AND TEST CONDITIONS						RESULTS				
Material	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Nylon	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/59	-	2.0
Teflon	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/59	-	2.0
Kel-F (Unplasticized)	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/59	-	2.0
Kel-F (Plasticized)	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2C	225	3	10	1	0	0	9/59	-	2.0

TABLE 15  
AGING OF COMMERCIAL GASKETS AT GAINESVILLE, FLORIDA

GASKET				FIXTURES AND TEST CONDITIONS						RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Rubber	MIL-P-5315	O-Ring	0.139 X 4.984	Bolted	MR-73-2B	100	3	10	1	0	0	4/59	-	2.5
"	MIL-P-5315	"	0.139 X 4.984	Bolted	MR-73-3B	100	3	10	1	0	0	4/59	-	2.5
"	MIL-P-5315	"	0.139 X 4.609	Bolted	MR-73-6B	750	3	10	1	0	0	4/59	-	2.5
"	MIL-P-5315	"	0.139 X 3.359	Marman	MR-73-8A	100	3	10	1	0	0	4/59	-	2.5
"	MIL-P-5315	"	0.139 X 3.359	Marman	MR-73-7A	100	2	10	1	0	0	4/59	-	2.5
"	NA2-4062	"	0.210 X 19.5	Bolted	MR-73-1	750	3	410	1	0	0	4/59	-	2.5
"	MIL-P-5315	"	0.070 X 0.145	Valve (MV-74)	MR-73-10	750	3	160	2	0	0	4/59	-	2.5
"	MIL-C-5510	"	0.070 X 0.364	"										
"	MIL-P-5516	"	0.072 X 0.351	"										
"	"	"	0.103 X 0.612	"										
"	"	"	0.069 X 0.070	Valve (MV-76)	MR-73-9	2000	3	80	3	0	0	4/59	-	2.5
"	"	"	0.070 X 0.239	"										
"	"	"	0.070 X 0.516	"										
"	"	"	0.078 X 0.468	"										
"	"	"	0.103 X 0.487	"										
"	MIL-P-5315	"	0.072 X 0.351	Valve (LOX)	MR-73-11	750/40	3	160/160	4	2(1)	140/180	9/59	10/61	2.0
"	MIL-P-5315	"	0.097 X 0.755	"										
Composition	Allpax SH-500	Flat	5.375 X 4.625 X .062	Bolted	MR-73-3C	50	3	10	1	0	0	9/59	-	2.0
"	"	"	"	"	MR-73-2C	225	3	10	1	0	0	9/59	-	2.0
"	"	"	"	"	MR-73-2D	225	3	10	1	0	0	9/59	-	2.0
"	"	"	"	"	MR-73-2D	500	3	10	1	2	27	9/59	10/61	2.0
Flexitallic	304 SS Asb.	Flat	5.218 X 4.778 X .125	Bolted	MR-73-2A	75	6	10	1	0	0	9/59	-	2.0
"	304 SS Asb.	"	5.218 X 4.778 X .125	"	MR-73-3A	200	3	10	1	0	0	9/59	-	2.0
"	301 SS Asb.	"	5.08 X 4.72 X .125	"	MR-73-6A	750	6	10	1	6	550	4/59	4/60	1.0
"	301 SS Asb.	"	5.08 X 4.72 X .125	"	MR-73-5A	750	3	10	1	3(2)	17	4/59	9/60	1.5
"	304 SS Asb.	"	3.968 X 3.520 X .125	Marman	MR-73-7C	75	3	10	1	0	0	9/59	-	2.0
"	304 SS Asb.	"	3.968 X 3.520 X .125	"	MR-73-8C	225	6	10	1	2	2	9/59	-	2.0
Toruseal	321 SS	O-Ring	0.064 X 3.72	Marman	MR-73-7B	100	3	10	1	0	0	4/59	-	2.5
"	"	"	0.064 X 3.72	"	MR-73-8B	100	3	10	1	0	0	4/59	-	2.5

(1) 1 Valve failed 4/61.  
(2) 2 Failed.

TABLE 16  
EFFECT OF PRESSURE ON AGING CHARACTERISTICS  
OF RUBBER GASKETS AT MSFC

GASKET					FIXTURES AND TEST CONDITIONS					RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Acrylic	RA-32570A	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	200	1	10	1	0	0	10/61	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	"	"	"	"	800	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
Butyl	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-25770B	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	"	"	"	"	800	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
Nitrile	"	"	"	"	"	500	1	10	1	0	0	"	--	--
	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-30870BN	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	"	"	"	"	800	1	10	1	0	0	"	--	--
SBR	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-20770BS	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
Hypalon	"	"	"	"	"	800	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
	"	"	"	"	"	1000	1	10	1	1	1	"	--	--
	RA-32970H	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	"	"	"	"	800	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
	"	"	"	"	"	1000	1	10	1	0	0	"	--	--

TABLE 16 (CONT'D)  
EFFECT OF PRESSURE ON AGING CHARACTERISTICS  
OF RUBBER GASKETS AT MSFC

GASKET					FIXTURES AND TEST CONDITIONS					RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test
Kel-F	RA-27170KF	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	200	1	10	1	0	0	10/61	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	"	"	"	"	800	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
Fluoro-Silicone	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-27870LS	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
Natural	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-23070N	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
Neoprene	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-24270NE	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--
Silicone	"	"	"	"	"	1000	1	10	1	0	0	"	--	--
	RA-28670SI	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--
	"	"	"	"	"	400	1	10	1	0	0	"	--	--
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--
	"	"	"	"	"	500	1	10	1	0	0	"	--	--



TABLE 16 (CONT'D)  
EFFECT OF PRESSURE ON AGING CHARACTERISTICS  
OF RUBBER GASKETS AT MSFC

GASKET				FIXTURES AND TEST CONDITIONS							RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test	
Thiokol	RA-31970T	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	200	1	10	1	0	0	10/61	--	--	
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--	
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--	
Urethane	RA-33370U	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--	
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--	
Viton-A	RA-26470VA	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--	
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--	
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--	

TABLE 17

EFFECT OF PRESSURE ON AGING CHARACTERISTICS OF  
RUBBER GASKETS AT GAINESVILLE, FLORIDA

GASKET					FIXTURES AND TEST CONDITIONS							RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test		
Acrylic	RA-32570A	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	200	1	10	1	0	0	10/61	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
Butyl	RA-25770B	"	"	"	"	1000	1	10	1	0	0	"	--	--		
"	"	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
Nitrile	RA-30870BN	"	"	"	"	1000	1	10	1	0	0	"	--	--		
"	"	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	1	1	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
SBR	RA-20770BS	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	1	7	"	--	--		
Hypalon	RA-32970H	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	1	24	"	10/61	0		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		

TABLE 17 (CONT'D)  
EFFECT OF PRESSURE ON AGING CHARACTERISTICS OF  
RUBBER GASKETS AT GAINESVILLE, FLORIDA

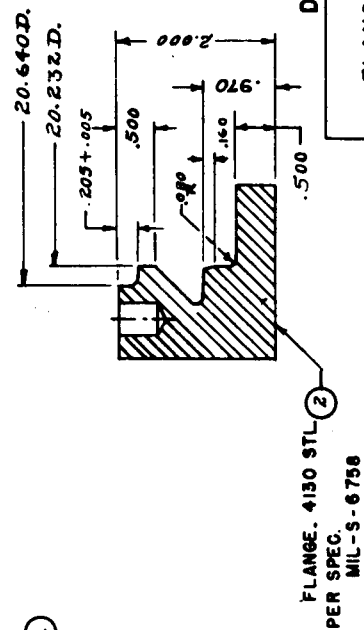
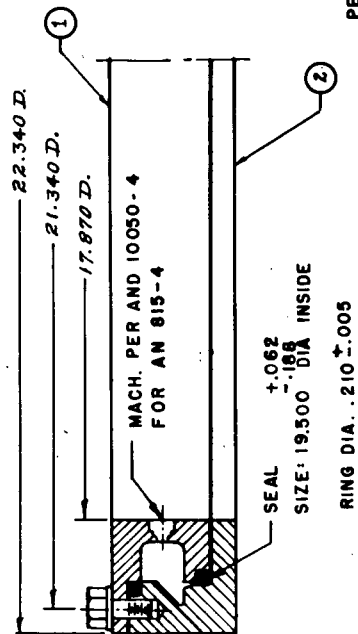
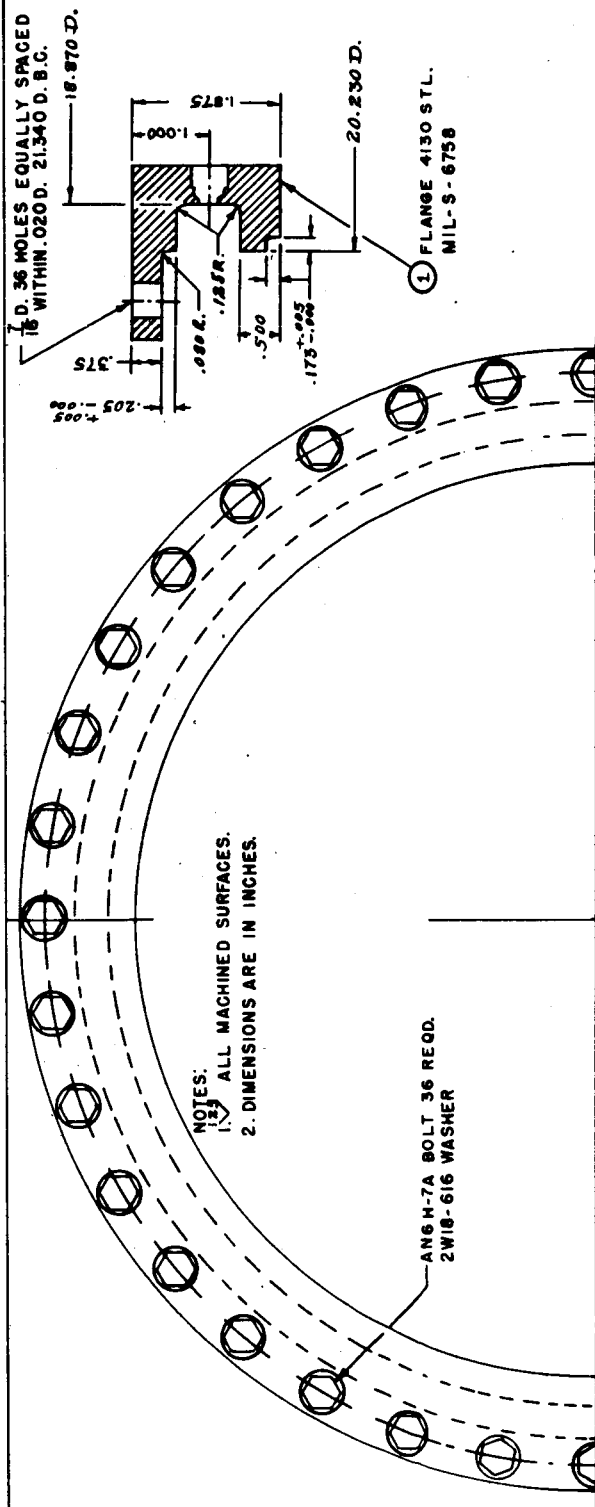
GASKET					FIXTURES AND TEST CONDITIONS							RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test		
Kel-F	RA-2717OKF	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	200	1	10	1	0	0	10/61	--	--		
	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
Fluoro-Silicone	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
	RA-27870LS	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
Natural	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
	RA-23070N	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
Neoprene	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
	RA-24270NE	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	1	2	"	--	--		
Silicone	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
	RA-28670SI	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		

TABLE 17 (CONT'D)

EFFECT OF PRESSURE ON AGING CHARACTERISTICS OF  
RUBBER GASKETS AT GAINESVILLE, FLORIDA

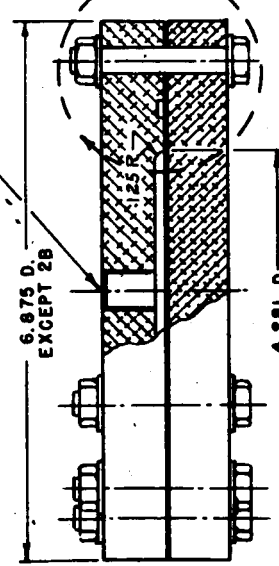
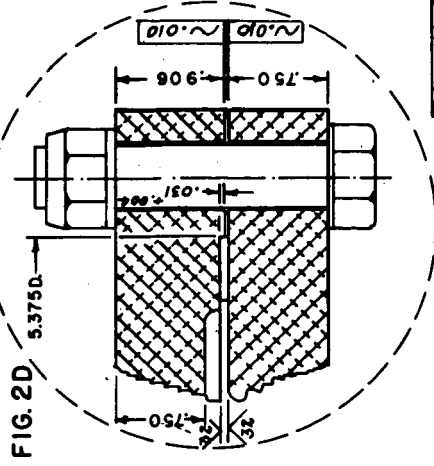
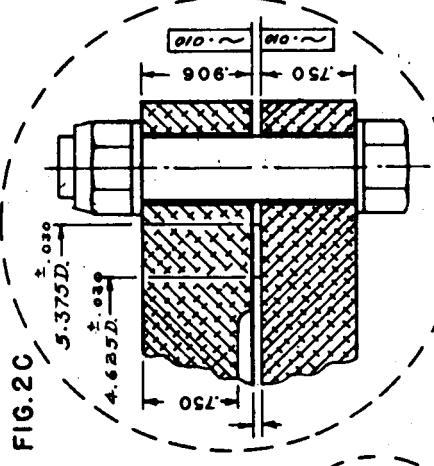
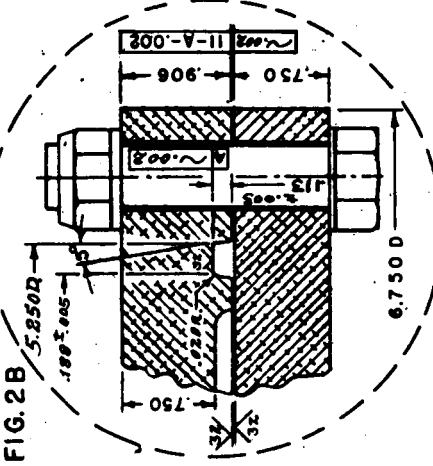
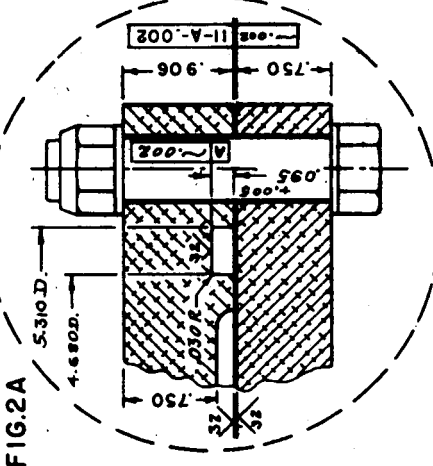
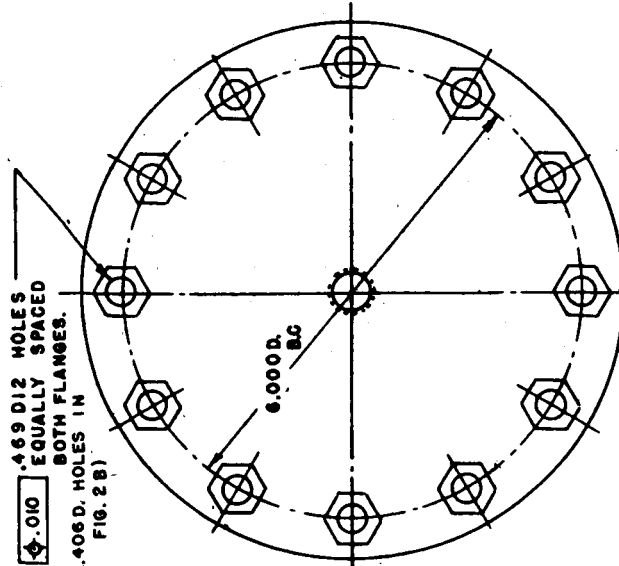
GASKET					FIXTURES AND TEST CONDITIONS							RESULTS				
Material	Sample Designation	Type	Size (Inches)	Fixture Type	Drawing Number	Test Pressure (psi.)	No. of Specimens On Test	Leaks Allowed (ml/min)	Test Procedure Number	Number Specimens Leaking	Leak Rate (ml/min)	Date Installed	Date Failed	Years On Test		
Thiokol	RA-31970T	Flat	5.375 X 4.625 X .062	Bolted	MR-73-2D	200	1	10	1	0	0	10/61	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
Urethane	RA-33370U	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		
Viton-A	RA-26470VA	Flat	5.375 X 4.625 X .062	"	MR-73-2D	200	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	400	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	800	1	10	1	0	0	"	--	--		
"	"	O-Ring	0.139 X 4.609	"	MR-73-4B	250	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	500	1	10	1	0	0	"	--	--		
"	"	"	"	"	"	1000	1	10	1	0	0	"	--	--		

# APPENDIX B



DWG. NO. MR-73-1

FLANGE ASSEMBLY  
THRUST CHAMBER

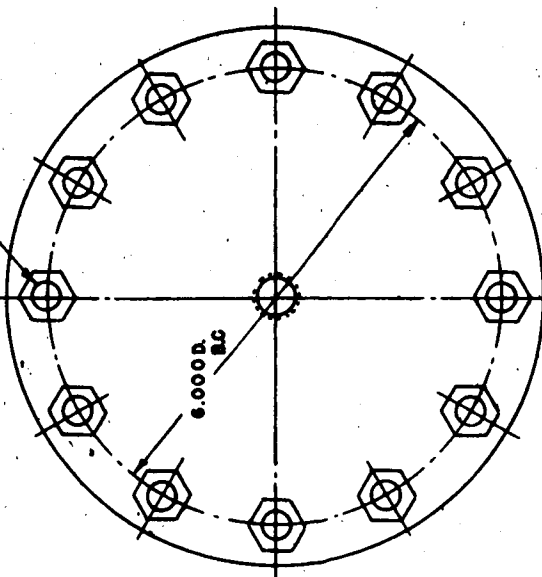


- NOTES:
1. ALL OVER EXCEPT AS SHOWN.
  2. DIMENSIONS ARE IN INCHES.
  3. FLANGE MATERIAL-6061 T6 AL ALLOY.  
(ANODIZE PER MIL-A-8625)

DWG. NO. MR-73-2

GASKET TEST  
ASSEMBLY

$\phi .010$   
 .406 DI2 HOLES  
 EQUALLY SPACED  
 BOTH FLANGES.



MACH. PER AND 10050-4  
 FOR AN 815-4

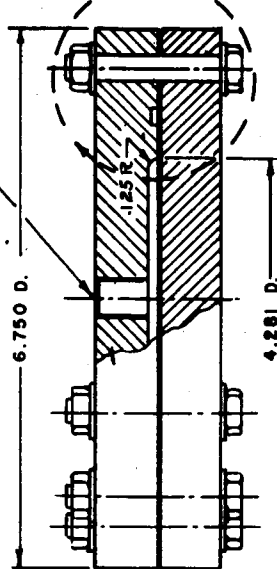


FIG. 3A

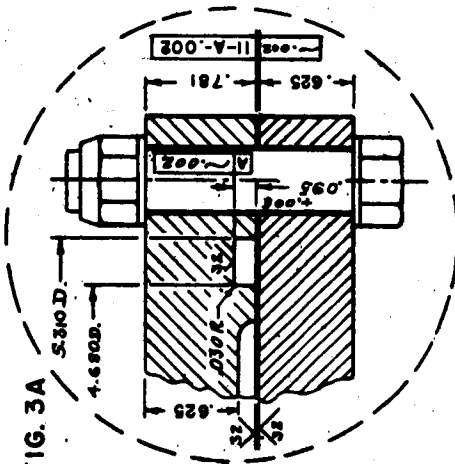


FIG. 3B

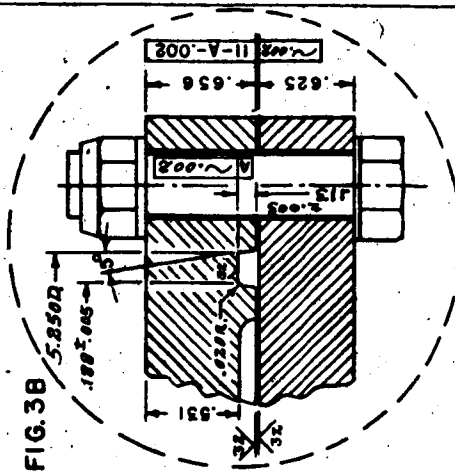
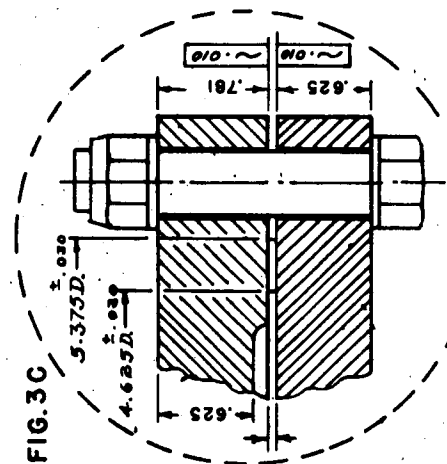


FIG. 3C



NOTES:

1. ALL OVER EXCEPT AS SHOWN.
2. DIMENSIONS ARE IN INCHES.
3. FLANGE MATERIAL - 321 CRES. STEEL

DWG NO. MR-73-3

GASKET TEST  
ASSEMBLY

.438 D Ø HOLES  
EQUALLY SPACED  
BOTH FLANGES.

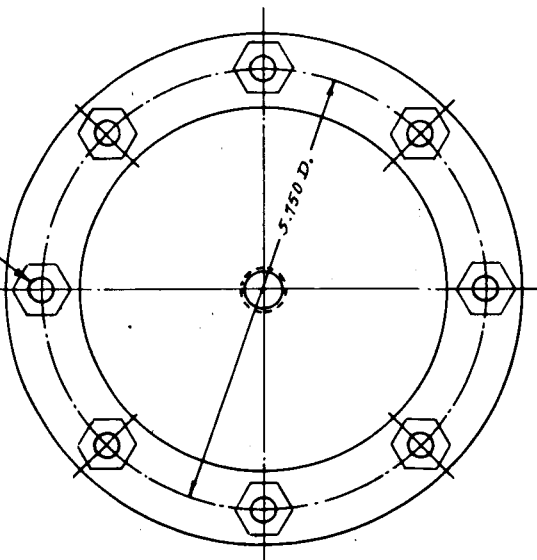


FIG. 4A

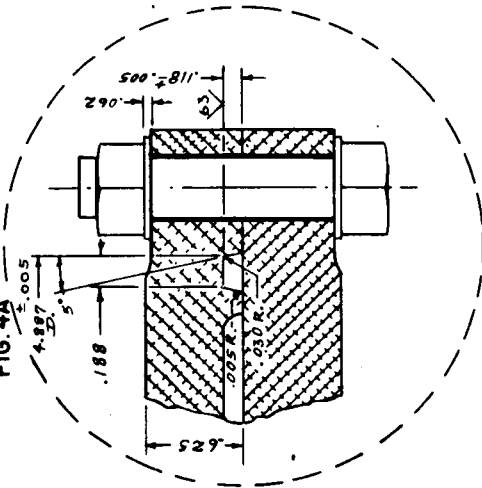
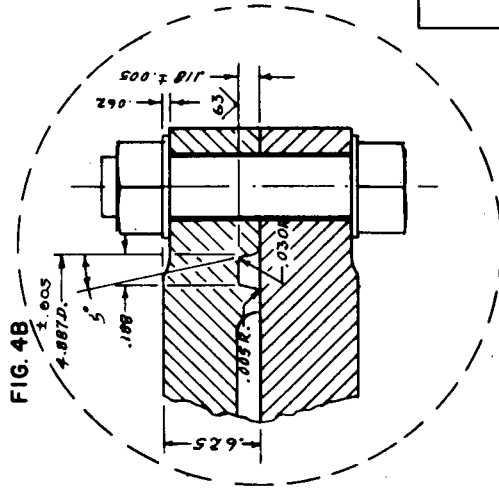


FIG. 4B

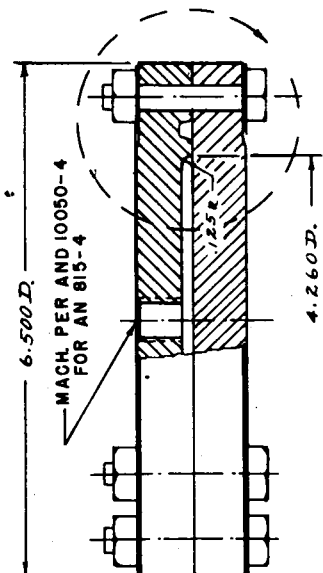


- NOTES:
1. DIMENSIONS ARE IN INCHES.
  2.  $\frac{.05}{.05}$  ALL MACHINED SURFACES UNLESS OTHERWISE SHOWN.
  3. 321 CRES STEEL—
  4. 6061 T6 AL ALLOY—  
(ANODIZE PER MIL-A-8625)



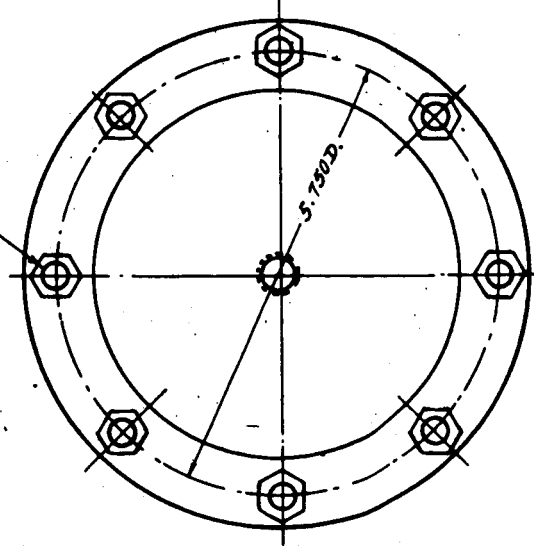
DWG. NO. MR-73-4

GASKET TEST  
ASSEMBLY





**.438 D 8 HOLES EQUALLY-  
SPACED BOTH FLANGES**



**FIG. 5A**

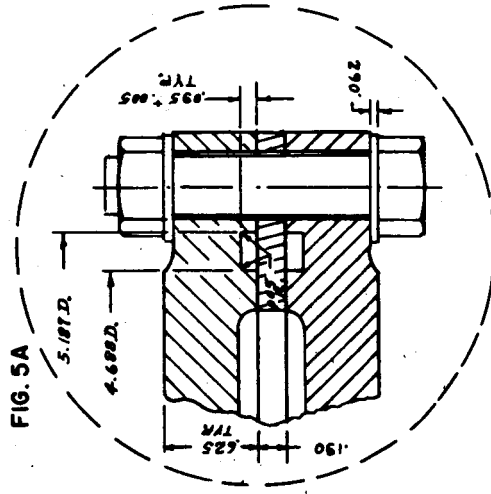
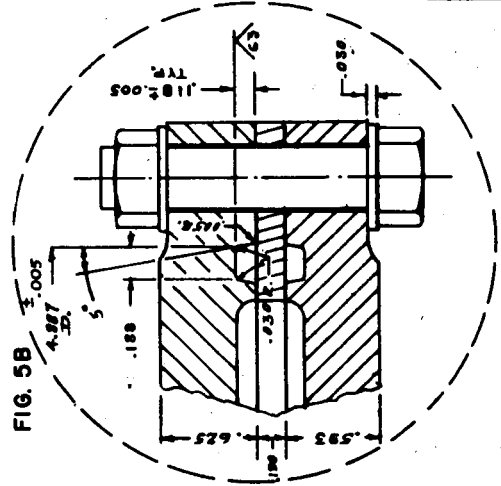


FIG. 5B

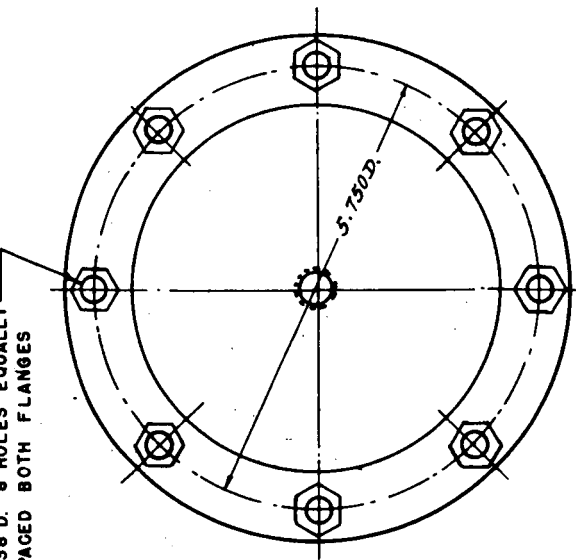


NOTES:

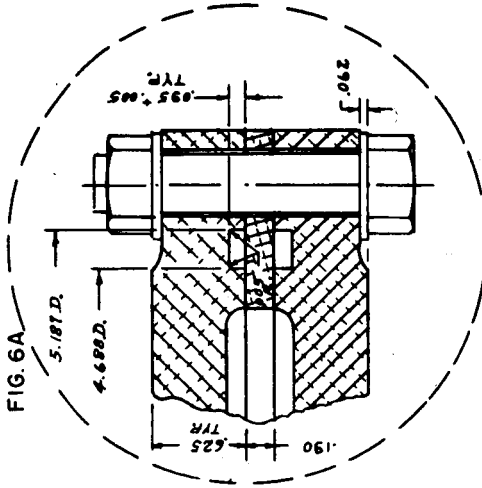
1. ALL DIMENSIONS ARE IN INCHES.
2. <sup>125</sup>/<sub>16</sub> ALL MACHINED SURFACES UNLESS OTHERWISE SHOWN.
3. FLANGE MATERIAL 321 CRES STEEL.

DWG. NO. MR-73-5

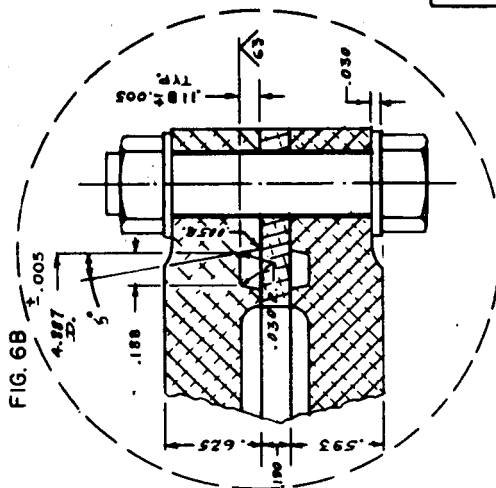
# GASKET TEST ASSEMBLY



**FIG. 6A.**



**FIG. 6B**



1. ALL DIMENSIONS ARE IN INCHES.  
2. <sup>125</sup> ALL MACHINED SURFACES  
UNLESS OTHERWISE SHOWN.  
3. FLANGE MATERIAL - 6061 T6  
AL ALLOY.

6.500 D.

MACH. PER AND 10050-4  
FOR AN815-4  
2 PLACES

1.25

4.260 I.D.  
FLANGES & PLATE

DWG. NO. MR-73-6

# GASKET TEST ASSEMBLY

CLAMP: MARMAN 4369-412-M  
EXCEPT PER NOTE "3"

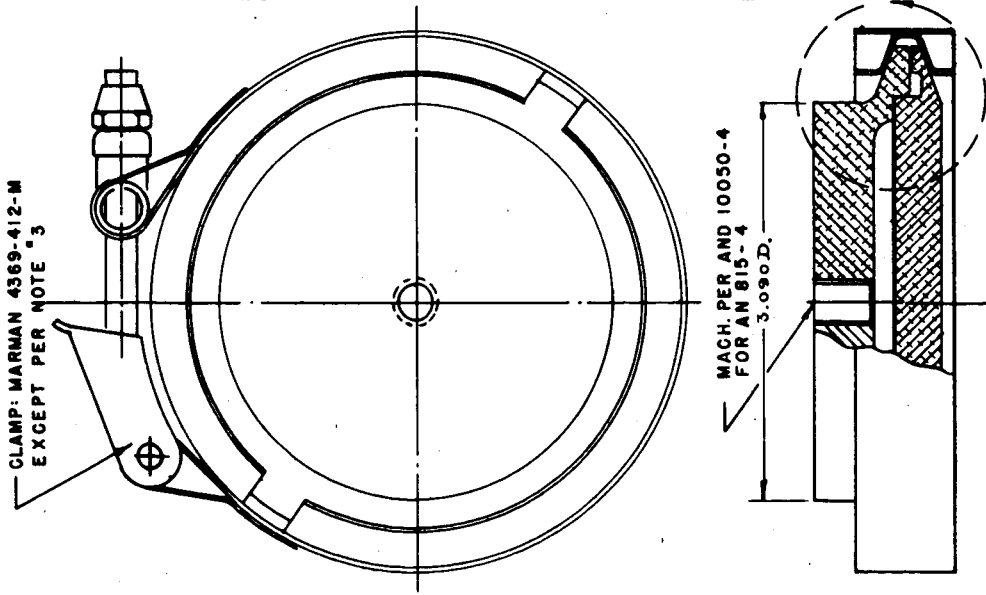


FIG. 7A

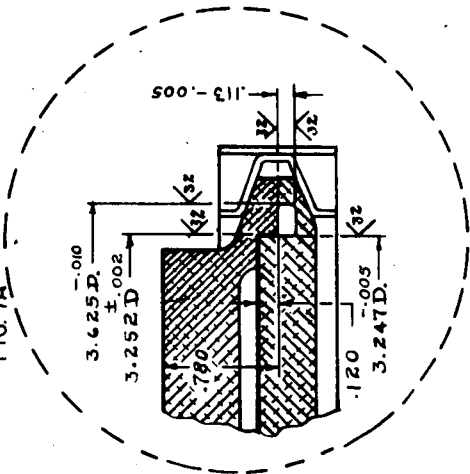


FIG. 7B

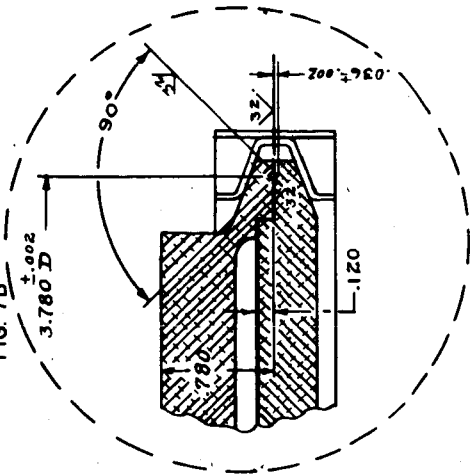
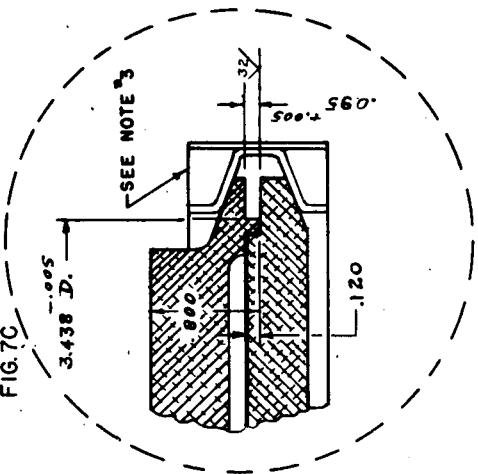


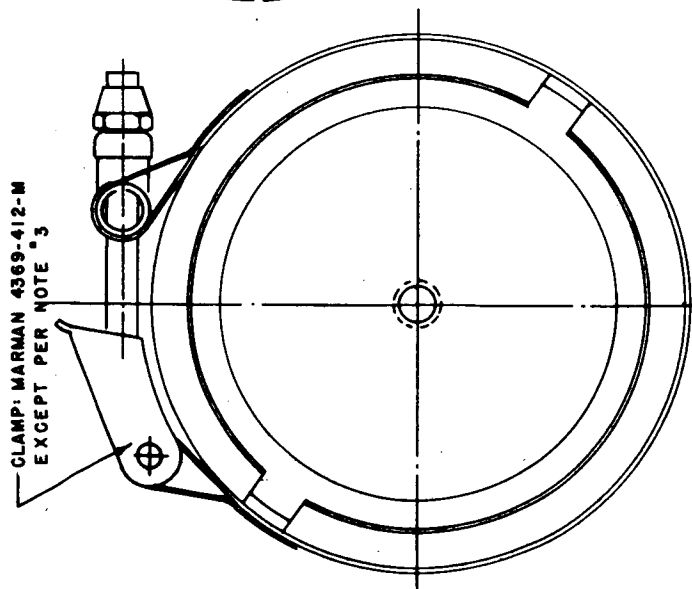
FIG. 7C



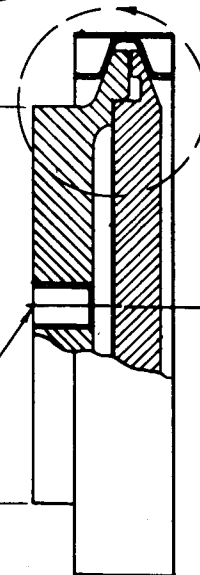
- NOTES:
1. ALL MACHINED SURFACES.
  2. DIMENSIONS ARE IN INCHES.
  3. MARMAN 4426-410-M
  4. 6061 T6 AL ALLOY — (ANODIZE PER MIL-A-8625)

DWG. NO. MR-73-7

GASKET TEST  
ASSEMBLY



MACH. PER AND 10050-4  
FOR AN 815-4  
3.090D.



**FIG. 8B**

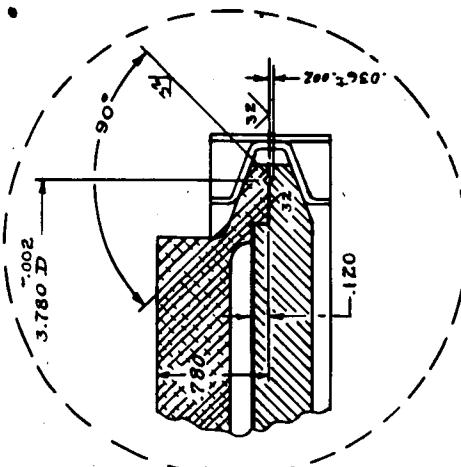
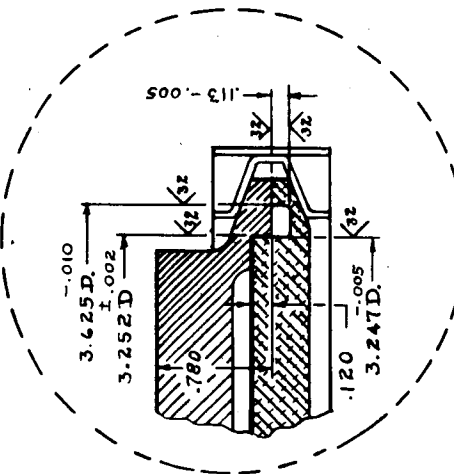
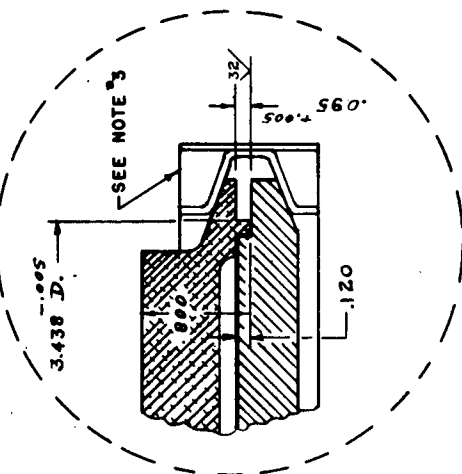


FIG. 8C

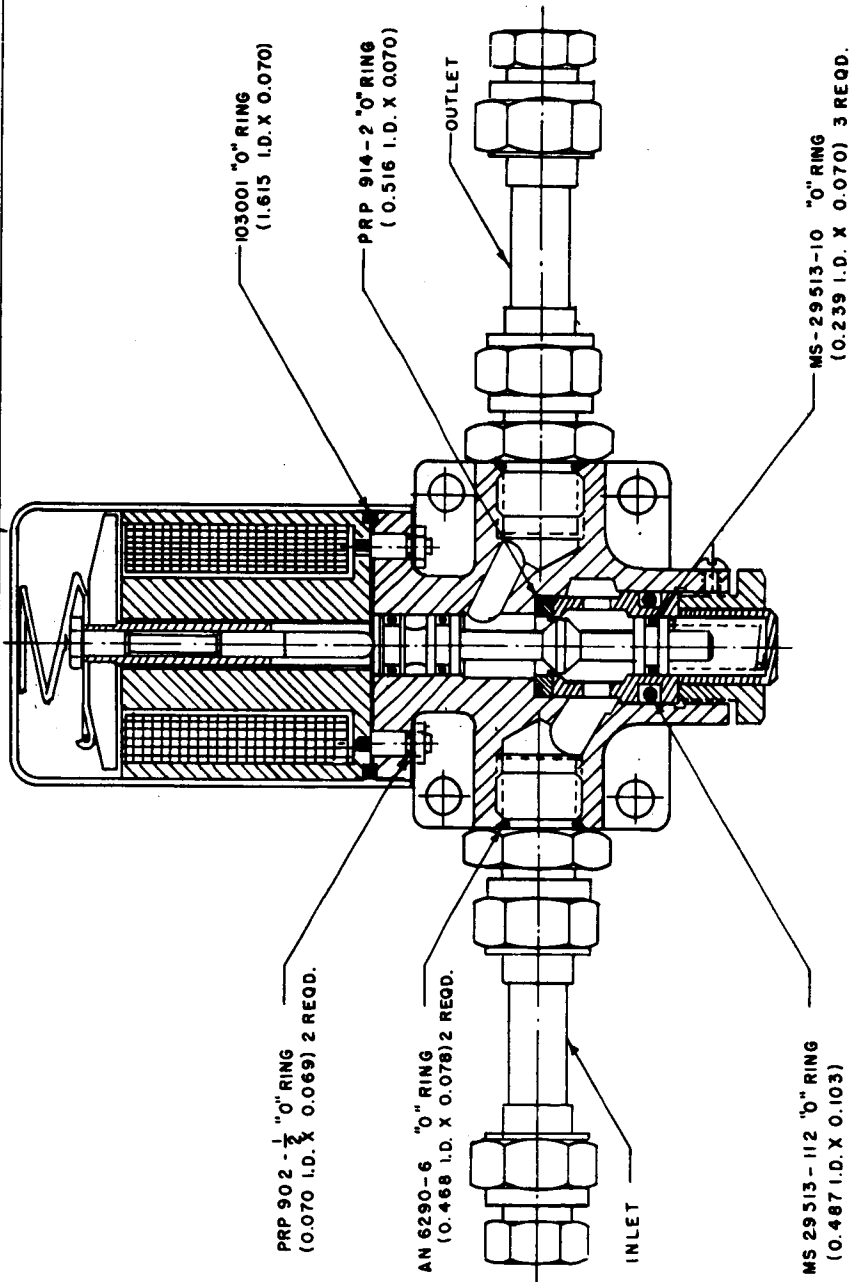


**NOTES:**

1. ALL MACHINED SURFACES.  
2. DIMENSIONS ARE IN INCHES.  
3. MARMAN 4426-410-M  
4. 6061 T6 AL ALLOY — (ANODIZE PER MIL-A-8625)

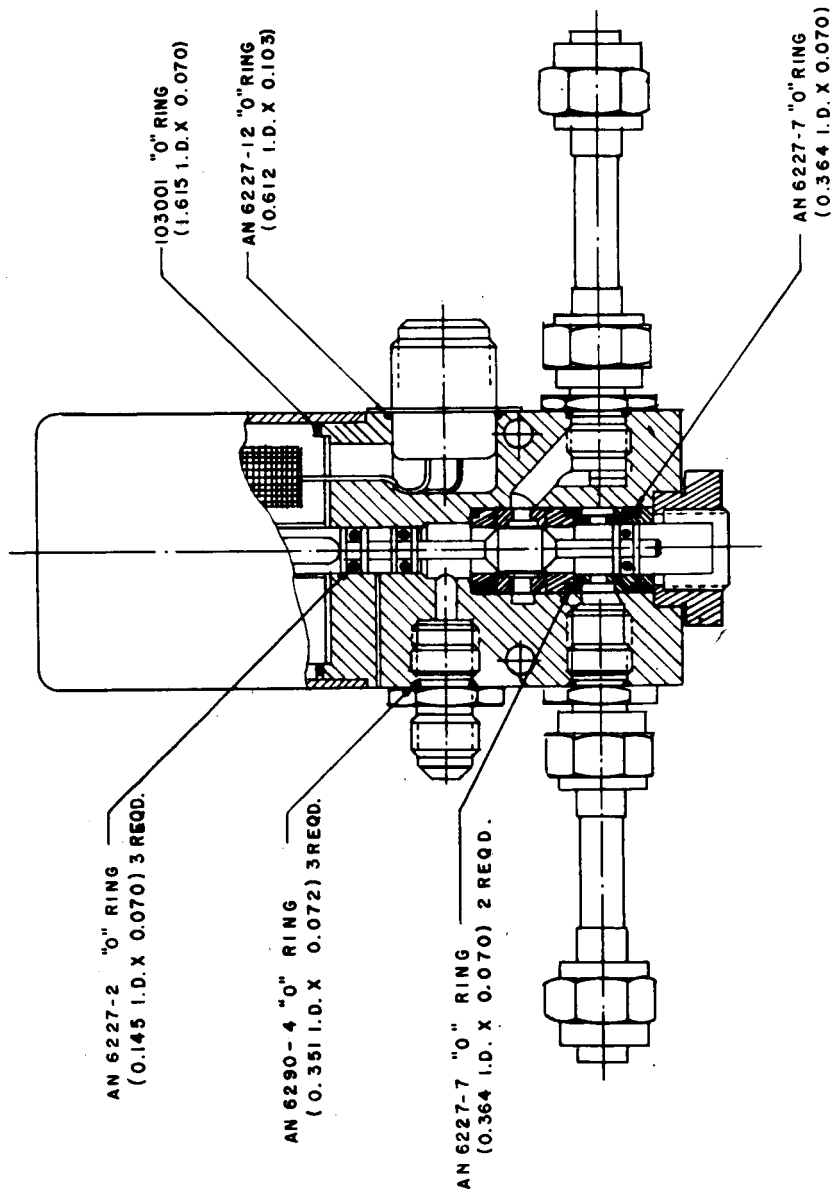
DWG. NO. MR-73-8

## GASKET TEST ASSEMBLY



DWG NO. MR-73-9

VALVE ASSEMBLY  
SOLENOID MV-76



DWG. NO. MR-73-10

CONTROL VALVE  
MV-74

GASKET SGM 148407  
SGM 144921

AN 6290-4 "O"RING  
(0.351 I.D. X 0.072)

AN 6290-4 "O"RING  
NOTE 1

AN 6290-10 "O"RING  
(0.755 I.D. X 0.097)

AN 6290-4 "O"RING  
NOTE 1

GASKET 8940017  
8940012

AN 6290-6 "O"RING  
NOTE 1

NOTE:

I. SIZE - 0.351 INSIDE DIA.  
RING DIA. 0.072

40 PSI

750  
PSI

DWG. NO. MR-73-11

LOX REPLENISHING  
VALVE

## APPENDIX C

## TEST PROCEDURE NO. 1

1. Close all valves and set Grove Regulator at zero.
2. Connect pressure supply hose from control panel to inlet port of test part.
3. Adjust Grove Regulator to the desired test pressure.
4. Immerse the pressurized fixture in the water vat.
5. After three minutes under pressure, measure and record the leakage rate.
6. Remove fixture from water vat and release pressure.
7. If the leakage rate was within allowed limits, replace test fixture on the test panel.
8. Remove the test fixtures which fail to meet prescribed standards from the installed gasket aging test.



## TEST PROCEDURE NO. 2

1. Close all valves and set Grove Regulator at zero.
2. Connect pressure supply hose from control panel to inlet port of valve. Cap outlet port.
3. Adjust inlet pressure to 750 psig.
4. Measure and record leakage out the vent port.
5. Connect the valve to a 24 volt D.C. power supply and repeat step 4.
6. Cycle the valve five times and repeat steps 4 and 5.
7. Cap vent port, with the solenoid energized, apply soap solution to valve body and estimate leakage, as evidenced by bubbling. Record this leakage also.
8. If valve meets requirements, release pressure and re-install on test panel.

## TEST PROCEDURE NO. 3

1. Close all valves and set Grove Regulator at zero.
2. Connect pressure supply hose from control panel to inlet port of valve.
3. Connect valve to a 24 volt D.C. power supply.
4. Adjust pressure to 2000 psig.
5. Measure and record leakage at outlet port.
6. Cycle valve five times and repeat step five.
7. Cap outlet port. In the energized position, apply soap solution to valve body. Estimate and record any observed leakage.
8. If valve meets requirements, release pressure and re-install on test panel.

## TEST PROCEDURE NO. 4

1. Close all valves and set Grove Regulator at zero.
2. Connect pressure supply hose from control panel to port on left hand end of valve (as mounted on test panel). Cap ports at right hand end and at bottom of valve.
3. Adjust inlet pressure to 40 psig.
4. Measure and record any leakage at outlet port on top of valve.
5. Apply soap solution to Marman clamp near left hand end of valve. Estimate and record any leakage.
6. Release pressure. Connect pressure supply hose from control panel to port at right hand end of valve (as mounted on test panel).
7. With inlet pressure at 40 psig, apply soap solution to Marman clamp near right hand end of valve. Estimate and record any leakage.
8. Release inlet pressure and connect pressure supply hose from control panel to port at bottom of valve.
9. Adjust inlet pressure to 750 psig.
10. Cycle valve five times, measure and record any leakage from upper and right hand end ports.
11. If valve meets requirements, release pressure and re-install on test panel.

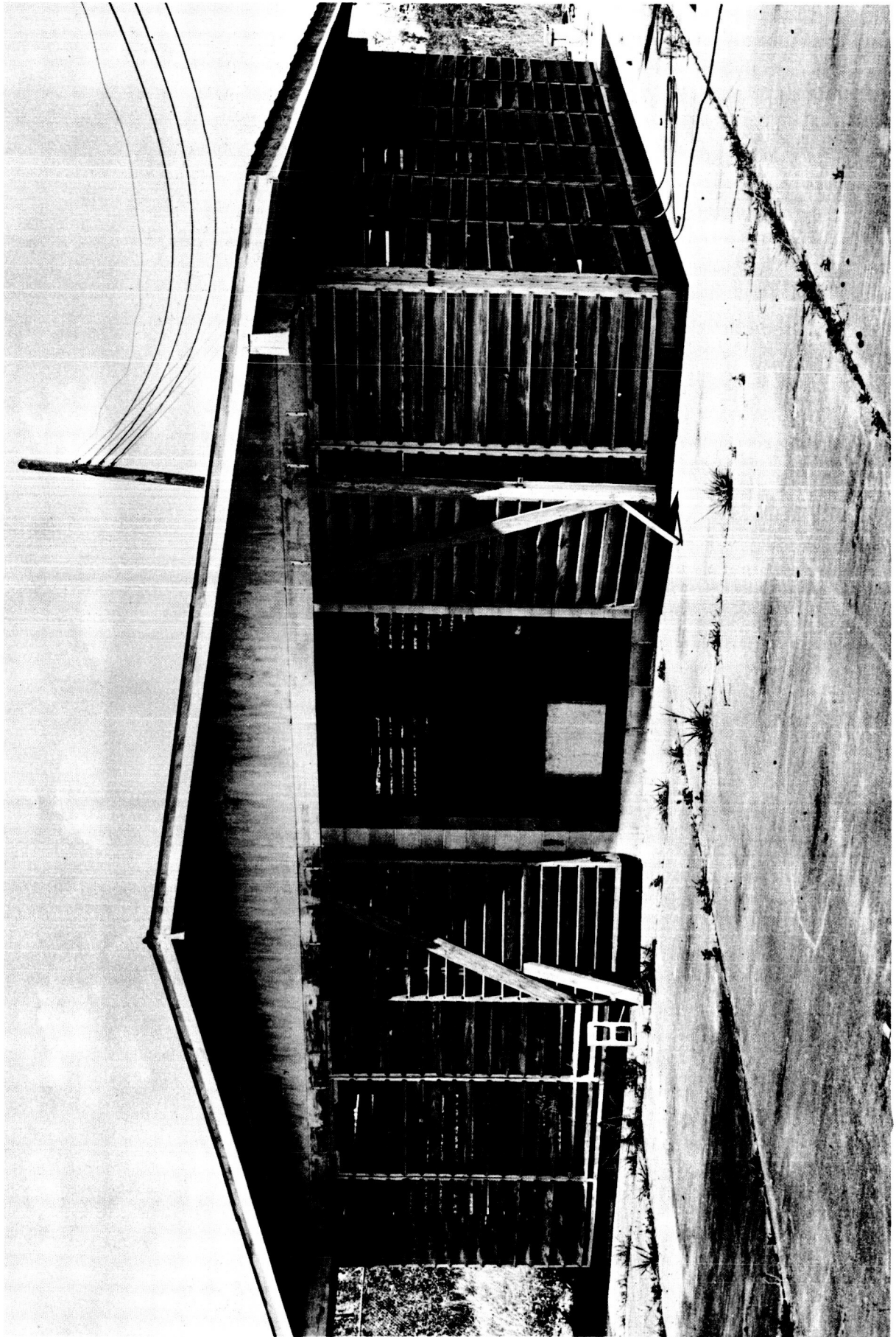


FIGURE 1 TEST FACILITIES AT GAINESVILLE, FLORIDA



FIGURE 2 TEST FIXTURE ASSEMBLY

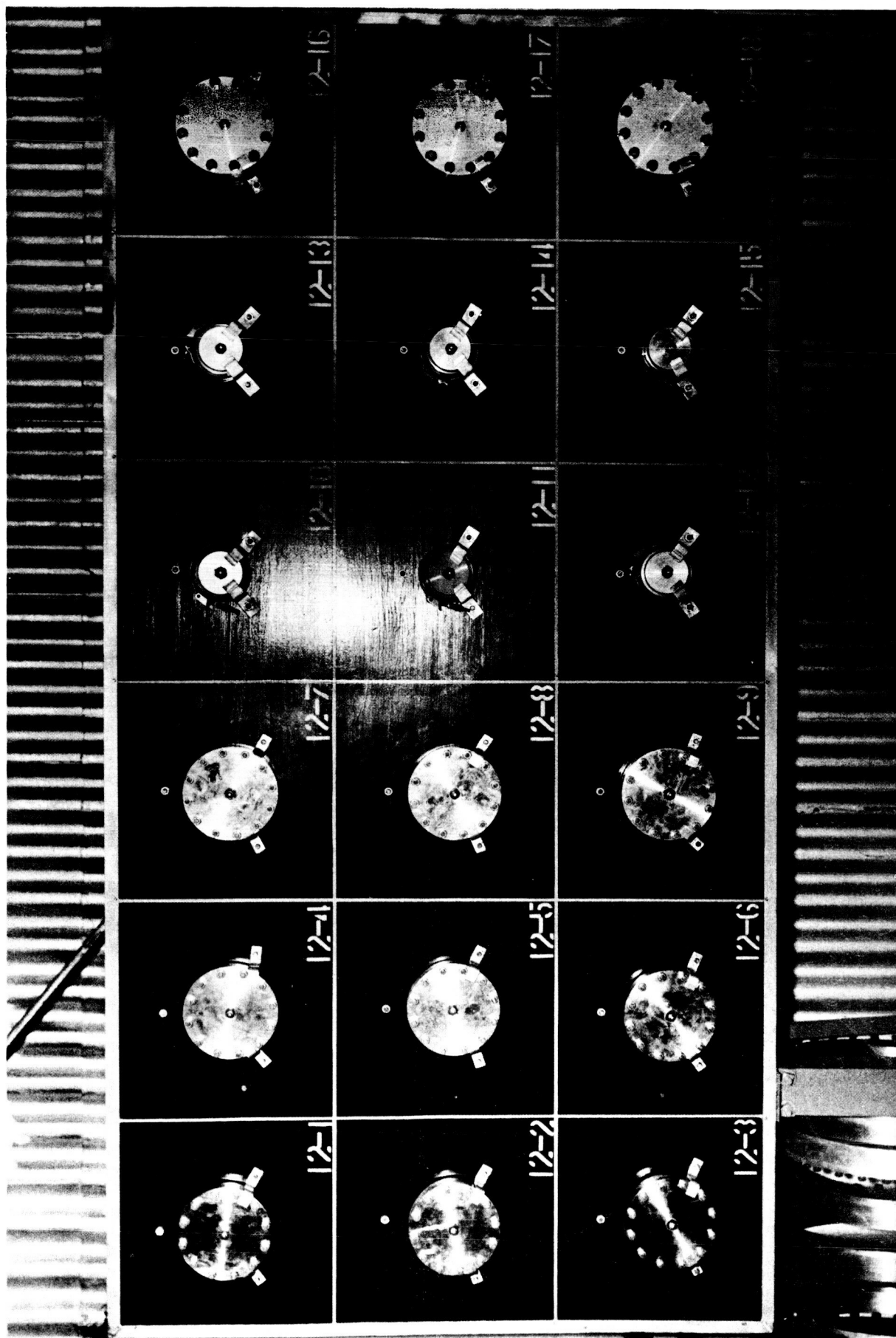


FIGURE 3 INSTALLED TEST FIXTURES

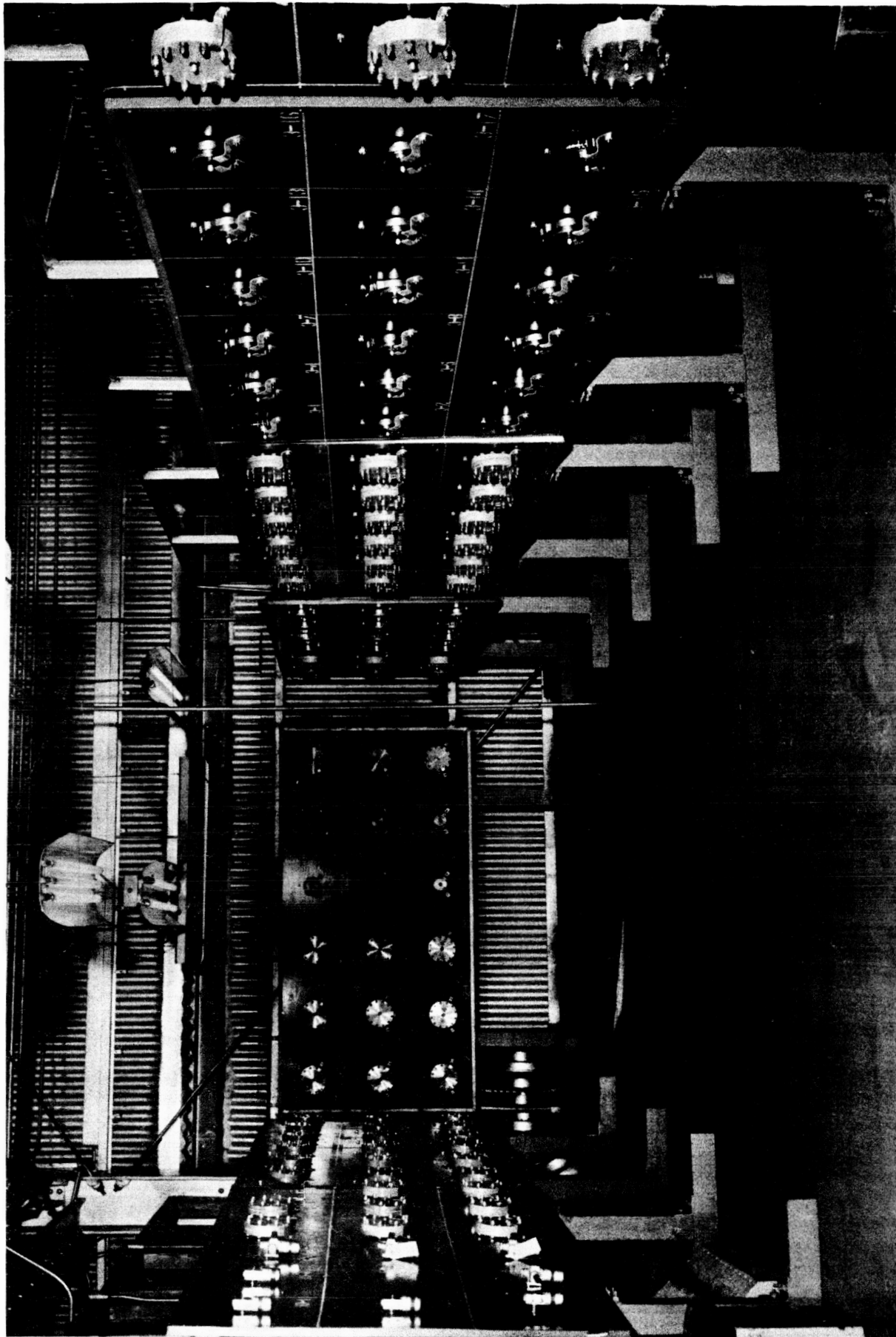


FIGURE 4 INSTALLED TEST FIXTURES AT MSFC



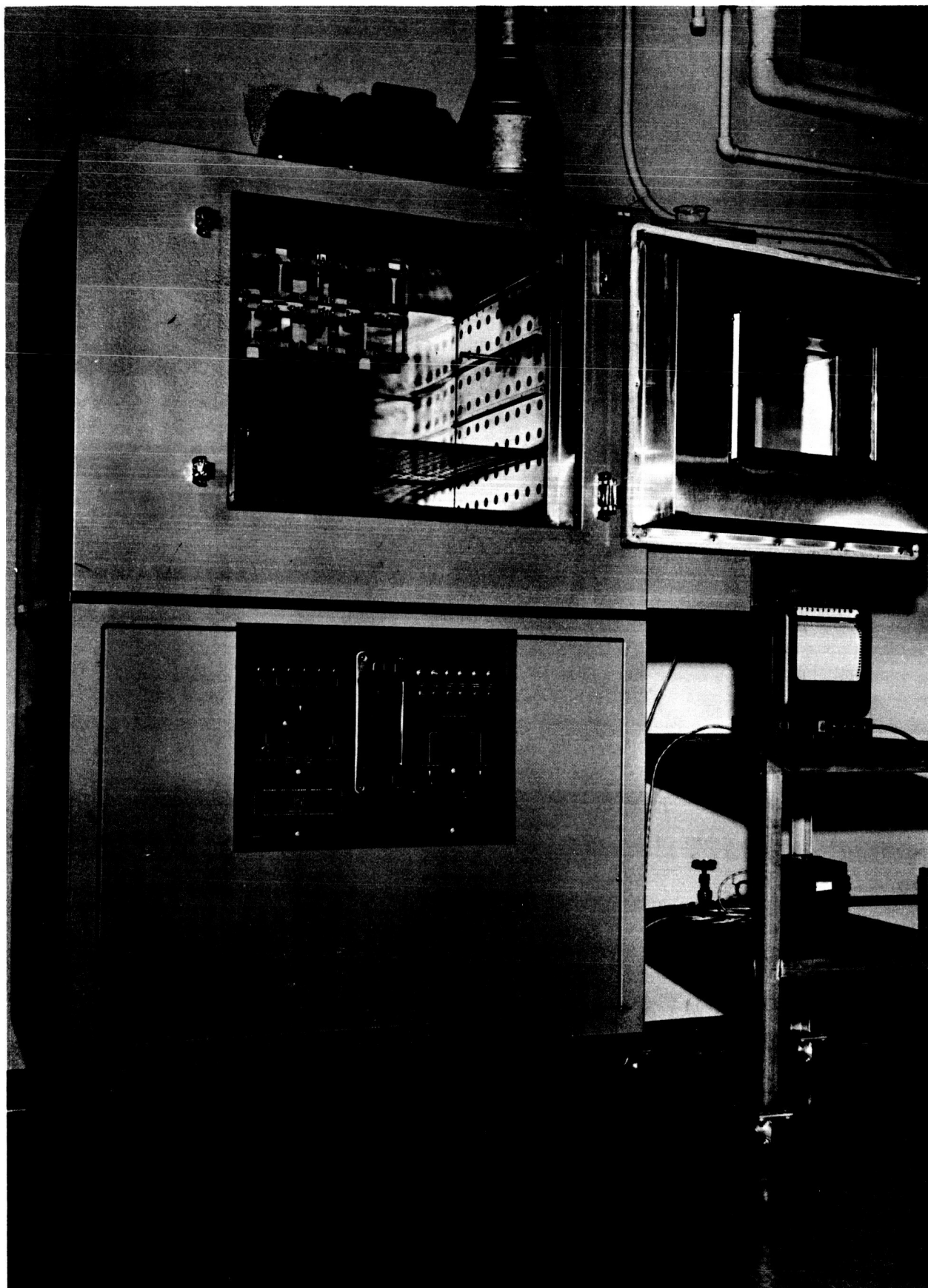


FIGURE 5 MAST OZONE TEST CHAMBER



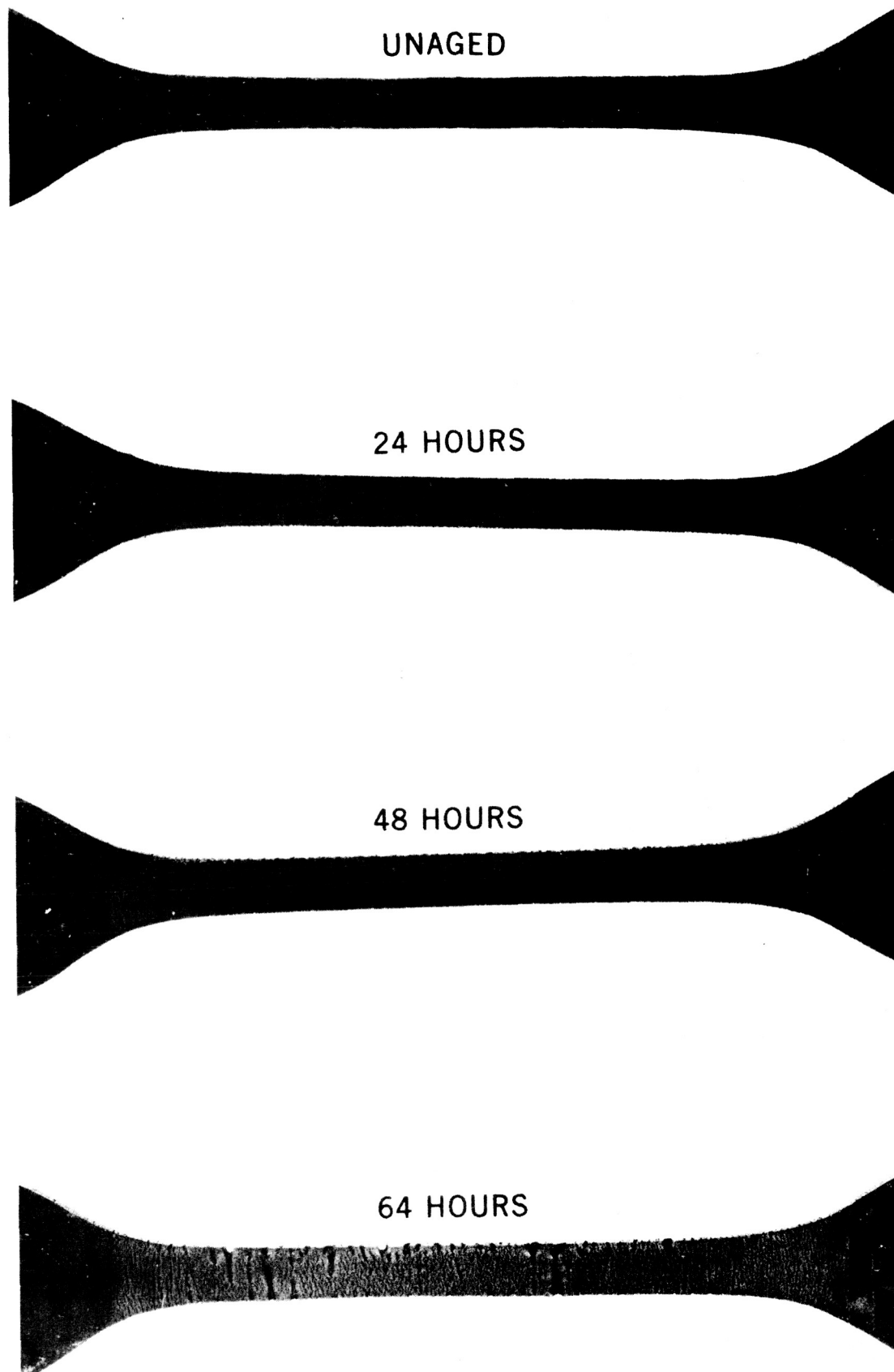


FIGURE 6 ACCELERATED OZONE AGING OF NATURAL RUBBER,  
25 PPHM OZONE AT AMBIENT TEMPERATURE

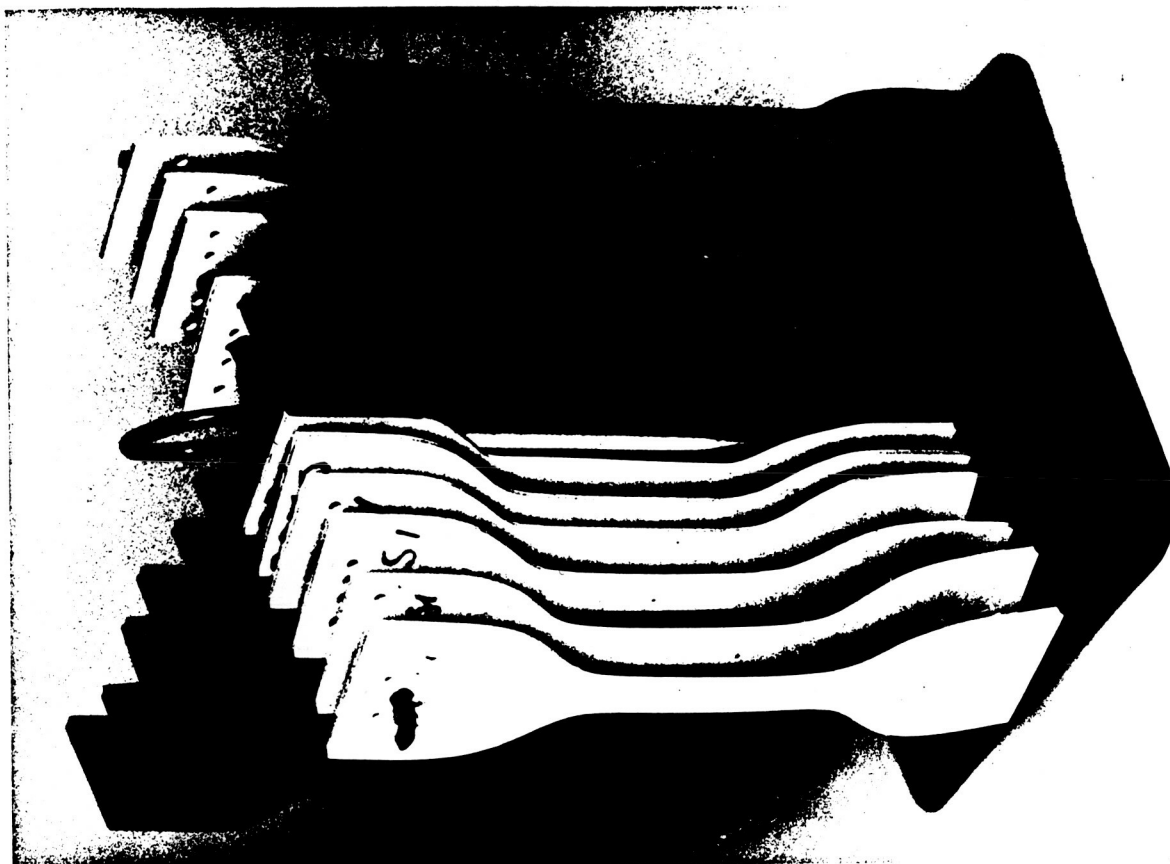


FIGURE 7b TEST SPECIMENS

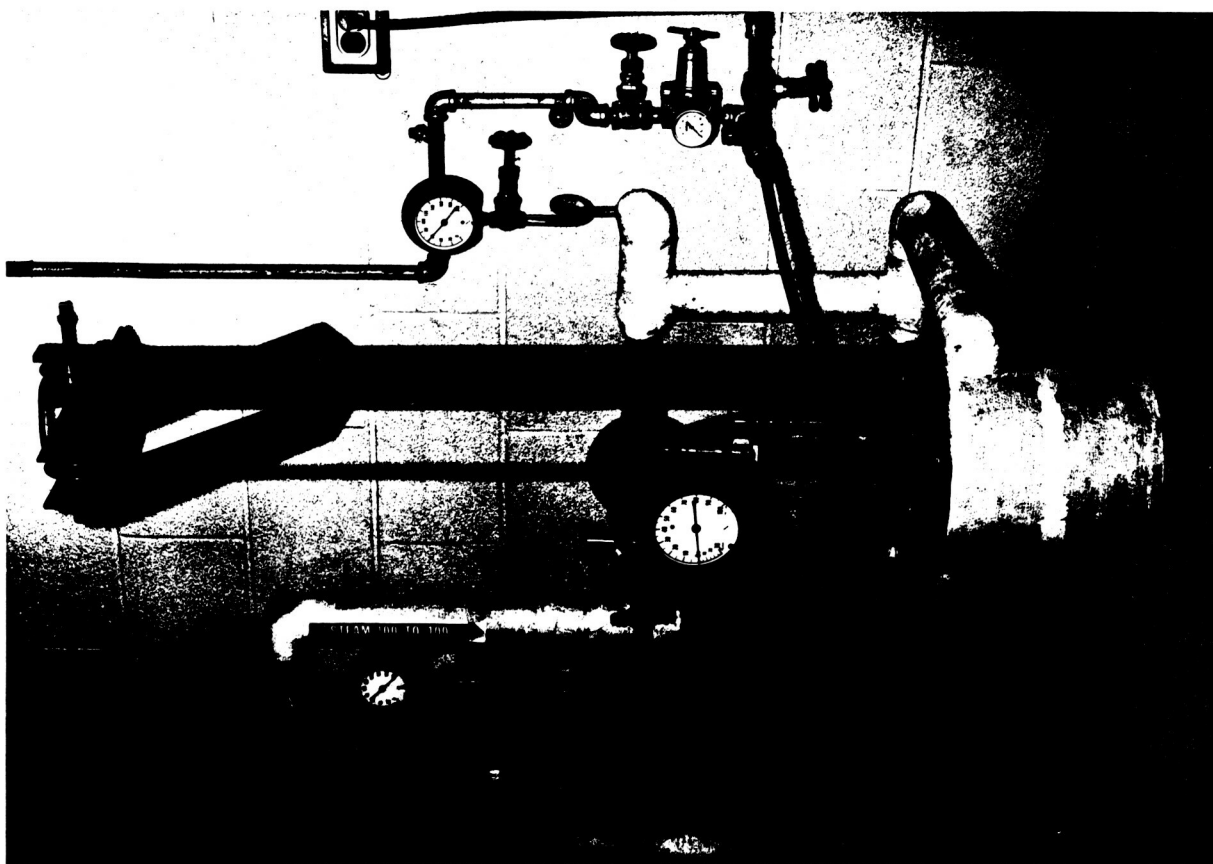


FIGURE 7a AIR BOMB APPARATUS

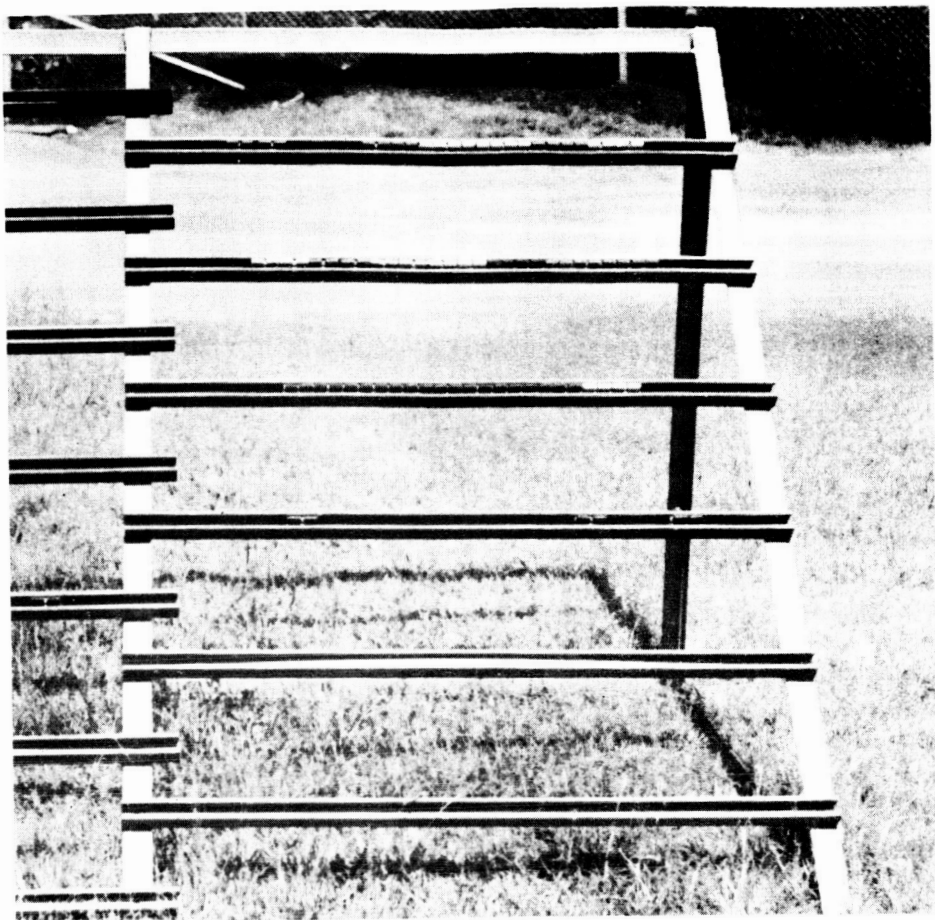


FIGURE 8a OUTDOOR AGING RACK

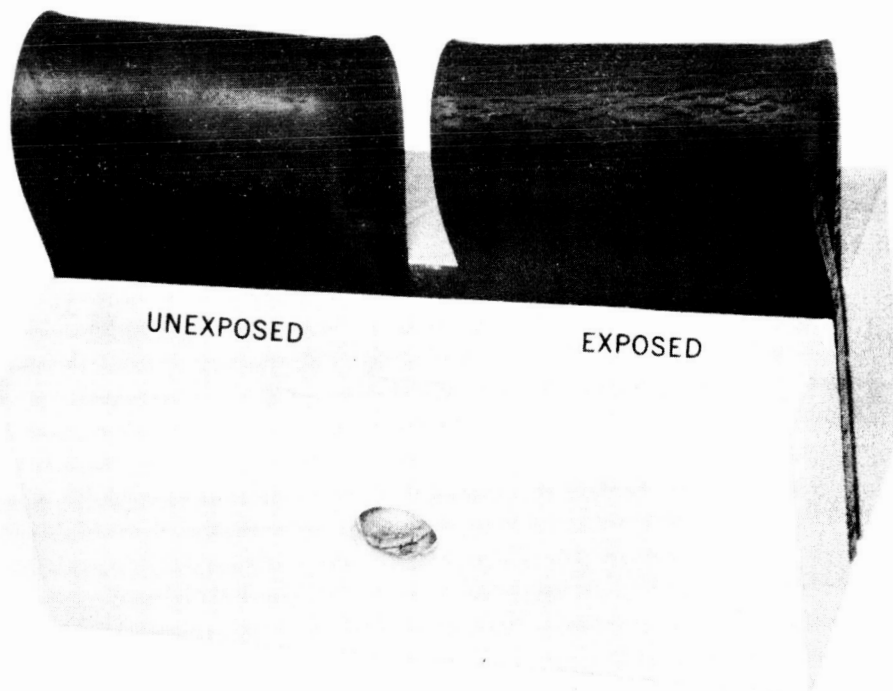
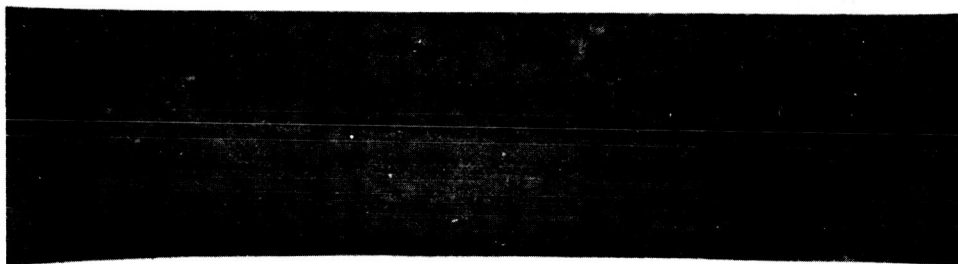


FIGURE 8b OUTDOOR AGING SPECIMENS

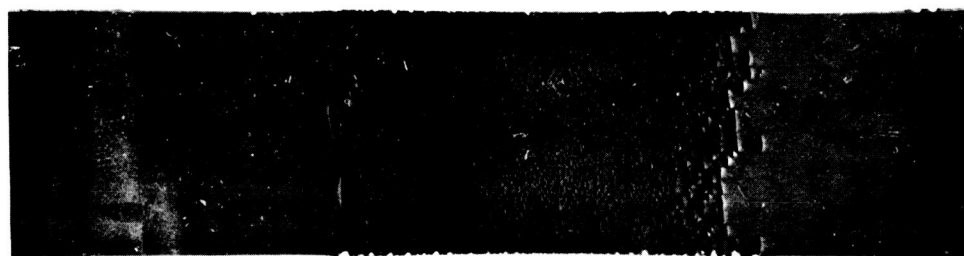
UNAGED



1 DAY



14 DAYS



35 DAYS

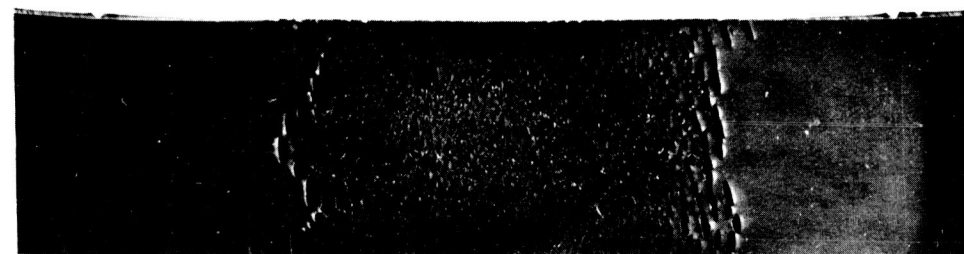


FIGURE 9 OUTDOOR AGING OF NATURAL RUBBER SHOWING THE DEVELOPMENT OF OZONE CRACK IN BENT LOOP SPECIMENS

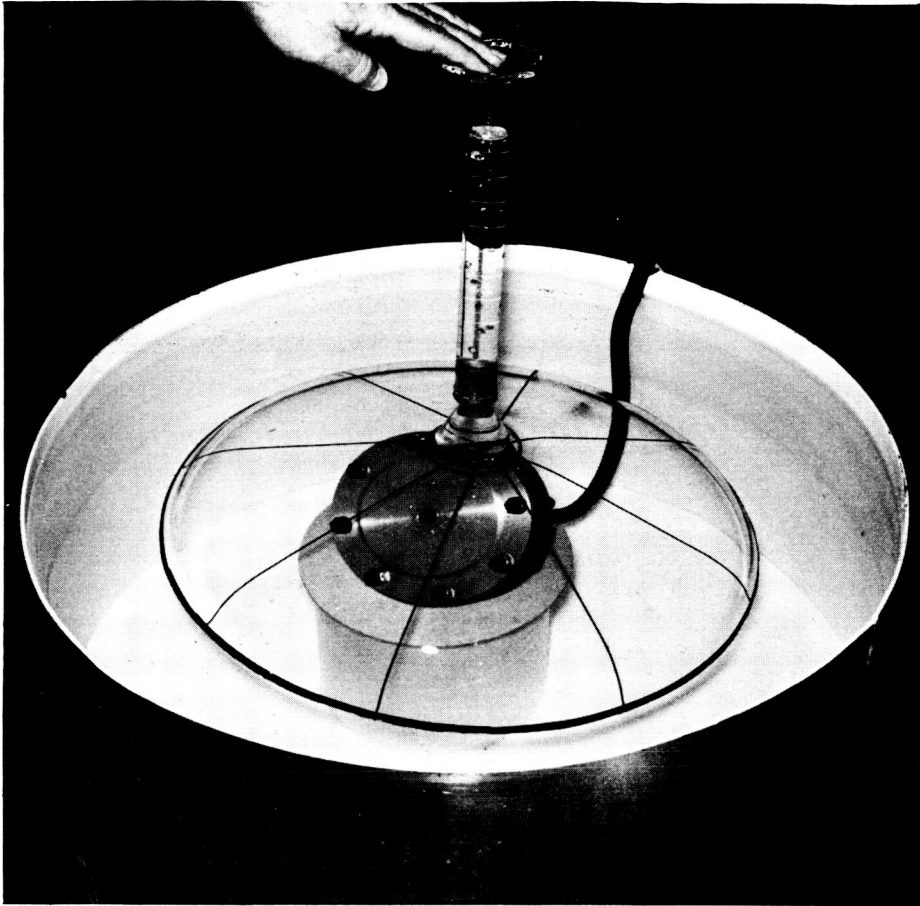


FIGURE 10a LEAK RATE MEASUREMENT

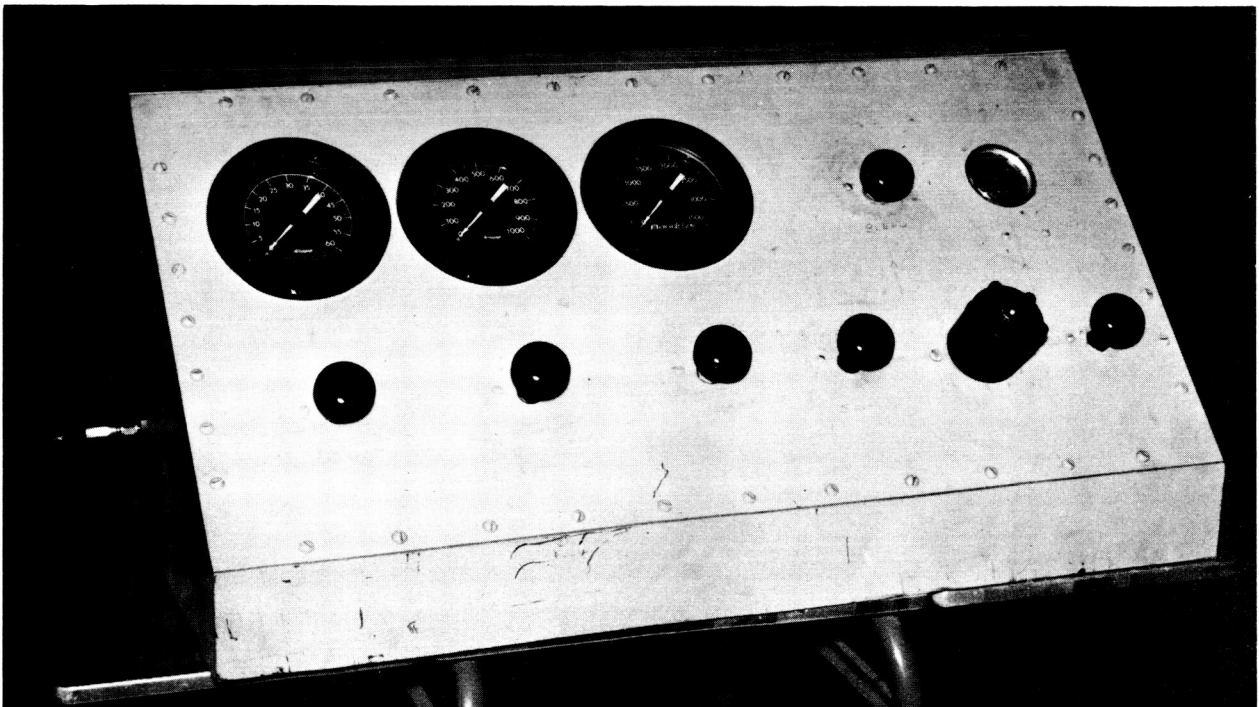


FIGURE 10b LEAK MEASUREMENT CONTROL PANEL

## REFERENCES

1. GEORGE G. WINSPEAR, "The Vanderbilt Rubber Handbook"; R. T. Vanderbilt Company, Inc. New York, N. Y.
2. A. RIECHE, R. MEISTER, H. SAUTHOFF, H. PFEIFFER, "Ozonides & Their Decomposition", Ann. 533, 187-249 (1942).
3. A. I. YAKUBCHIK, N. G. KASATKINA, T. E. PAVLOVSKAYA, "The Ozonization of Unsaturated Compound, III. The Addition of Ozone to Internal & External Double Bonds in Butadiene Rubber", Rubber Chem. & Tech. 32, 284-287 (1959).
4. A. I. YAKUBCHIK, N. G. KASATKINA, G. I. DEMIDOVA, G. B. FEDOROVA, "Oxidative Decomposition of the Ozonide of Butadiene Rubber", Rubber Chem. & Tech. 32, 288-294 (1959).
5. Z. T. OSSEFORT, "Ozone Resistance of Elastomeric Vulcanizates", Rubber Chem. & Tech. 32, 1088-1103 (1959).
6. C. R. NOLLER, J. F. CARSON, H. MARTIN, K. S. HAWKINS, "Relative Rates of Ozonation of Unsaturated Compounds", J. Am. Chem. Soc. 58, 24-26 (1936).
7. JOHN O. COLE & JAMES E. FIELD, "Oxidation of GR-S and Other Elastomers", Ind. Eng. Chem. 39, 174-179 (1947)..
8. G. R. MITCHELL & J. REID SHELTON, "Products of Oxidation of Olefin Structurally Related to GR-S", Rubber Chem. & Tech. 26, 528-542 (1953).
9. E. M. BEVILACQUA, "The Reaction of Molecular Oxygen with Rubber", Rubber Chem. & Tech. 30, 667-680 (1957).
10. E. M. BEVILACQUA, "End Groups of Oxidized Rubber", Rubber Chem. & Tech. 31, 86-88 (1958).
11. W. O. BAKER, "Cross-Linkage of Linear Polyesters by Free Radicals", J. Am. Chem. Soc. 69, 1125-1130 (1947).

APPROVAL

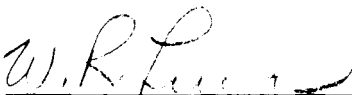
MTP-P&amp;VE-M-62-6

AGING OF INSTALLED RUBBER AND PLASTIC  
GASKETS IN SIMULATED FLIGHT HARDWARE

By

S. L. Burt  
J. M. Stuckey  
L. M. Thompson

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



---

W. R. LUCAS  
Chief, Engineering Materials Branch

---

W. A. MRAZEK  
Director,  
Propulsion and Vehicle Engineering Division

## DISTRIBUTION

M-DEP-R&D, Dr. Rees  
M-P&VE-DIR  
M-LOD -DIR  
M-TEST-Dir  
M-ASTR-DIR  
M-ME-DIR  
M-P&VE-F  
M-P&VE-S  
M-P&VE-SA  
M-P&VE-SB  
M-P&VE-P  
M-P&VE-PA  
M-P&VE-PL  
M-P&VE-PV  
M-P&VE-PT  
M-P&VE-PM  
M-P&VE-PE  
M-P&VE-PS  
M-P&VE-PD  
M-P&VE-E  
M-P&VE-EC  
M-P&VE-EL  
M-P&VE-EA  
M-P&VE-EP  
M-P&VE-M (5 cys)  
M-P&VE-MR (25 cys)  
M-P&VE-ADMP, Publications Section  
M-PAT, Mr. Warden  
M-MS-IP, Mr. Remer  
M-MS-H, Mr. Akens  
M-IPL (8 cys)  
M-P&VE-MG  
M-P&VE-MC  
M-P&VE-ME  
M-P&VE-MA  
M-HME-P